

# PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH



UNITED STATES DEPARTMENT OF AGRICULTURE  
BUREAU OF PUBLIC ROADS



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INTERCITY BUS LINE TERMINAL

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BUREAU OF PUBLIC ROADS

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H. S. FAIRBANK, Editor

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# THE MOTOR BUS AS A COMMON CARRIER

## AN ANALYSIS OF BUS OPERATION IN EIGHT STATES

Reported by HENRY R. TRUMBOWER, Economist, United States Bureau of Public Roads

**I**N THE expanding use of the highways there is no more interesting or significant phase than the recent remarkable increase in the number of motor busses operating as common carriers. Highway engineers, with one eye constantly on the motor vehicle registration statistics, have learned by hard experience to make ample provision in their plans for increases in highway utilization which are nothing short of phenomenal. They have learned also the wisdom of a most respectful consideration of the demands of the motor truck; but this latest comer among the users of their highways will bear very particular watching.

Less than 10 years ago these public passenger vehicles of the highways were practically unheard of. To-day, in the eight States which provide the statistics for this article, they operate regularly over a mileage of the public highways equal to 79 per cent of the railroad trackage in the same States.

In the beginning they were mainly converted passenger cars and trucks, comfortless and uninviting. To-day, although the statistics of the eight States show that substantially a third of the total number in operation are five and seven-passenger touring cars, there is a large and constantly increasing number of commodious, comfortable, specially-designed vehicles which operate over the improved State roads with all the regularity and punctuality of the railroads.

The best of these vehicles have separate upholstered chairs for each passenger. There is no crowding. They run smoothly and swiftly on pneumatic tires. They are electrically lighted, glass inclosed, and heated. Riding in them in the most inclement weather is as comfortable as in a Pullman car.

Is this a passing fad, or is it but the beginning of a great transportation service of the future? To what extent will the busses replace privately-owned passenger automobiles? What are the practical limits of size and capacity? How numerous will they become? How will they affect the railroads? What are the demands they will make upon highway design and location? To these questions there seem at present to be no certain answers, except the first. The warmth of the public reception accorded the new types of busses seems to leave no doubt that they will continue in operation and increase in numbers.

In a search for the trends which will indicate the probable future development as a basis for future highway design we have analyzed the data obtainable from the files and records of the public service commissions of eight States, namely: Arizona, Connecticut, Kentucky, Maryland, New Hampshire, Oregon, Washington, and West Virginia.<sup>1</sup> As it was the purpose of the investigation to evaluate with respect to their use by the common carrier vehicles only the rural highways, the data analyzed relate wholly to the service offered

between cities or between the cities and their suburbs. Data relating to strictly city operations have been excluded.

### THE NUMBER AND LENGTH OF MOTOR BUS ROUTES

In the eight States there are 705 separate routes over which motor busses operate in suburban or interurban service. These routes have a total length of 18,196 miles and an average length per route of 25.8 miles. But though this was the average length of all lines in the eight States, the average length was found to vary considerably as between States. This is shown by Table 1, from which it will be seen that the variation runs from an average length of 9.7 miles in New Hampshire to 60.5 miles in Arizona. This table apparently shows also that the length of routes is likely to be relatively short in such States as Connecticut, Maryland, and New Hampshire where the population is dense and the distance between population centers small; and long in States like Oregon and Arizona where the population is sparse or the distances between centers great.

TABLE 1.—Number and length of motor bus routes in the eight States

State	Number of routes	Total length of routes		Average length of route
		Miles	Miles	
Connecticut.....	53	924	17.4	
New Hampshire.....	32	311	9.7	
West Virginia.....	61	987	16.2	
Kentucky.....	189	3,876	20.5	
Arizona.....	39	2,358	60.5	
Oregon.....	81	3,739	46.1	
Washington.....	171	4,379	25.6	
Maryland.....	79	1,622	20.6	
Total.....	705	18,196	25.8	

<sup>1</sup> The total number of routes in the State is 189. Mileage data are available for only 171.

Considering all routes in the eight States, however, it is evident from Table 2 that the short routes exceed all others. Routes 19 miles long or less constitute 51.6 per cent of the total number, and those less than 30 miles in length are almost three-quarters of the total. On the other hand, the routes 50 miles in length and over form only 11.9 per cent of the total number. It is obvious, so far as those States are concerned at least, that motor-bus operations are characterized largely by short-distance movements.

### USE OF STATE HIGHWAYS AS BUS ROUTES

Excluding from the total mileage of the bus routes in the eight States 102 miles served by more than one route, the total mileage of highways used by the busses in these States is 18,094 miles, which constitute approximately 7 per cent of the total of 257,160 miles of highways in the same States, and 68 per cent of the mileage of the State highway systems, which, as shown by Table 3, is 26,610 miles.

<sup>1</sup> The data were obtained directly from the records of the public service commissions in the States of Connecticut, Maryland, and New Hampshire. For the other States the material analyzed was obtained from operating summaries published in mimeographed form by the American Electric Railway Association, compiled therefor by the State utilities commission.

TABLE 2.—Classification of motor-bus routes according to length

Length of route (miles)	Number of routes									Per cent
	Connecticut	New Hampshire	West Virginia	Kentucky	Arizona	Oregon	Washington	Maryland	Total	
0-9	17	21	23	34	6	11	28	21	161	22.8
10-19	10	9	18	64	11	18	44	29	203	28.8
20-29	19		12	53	3	14	30	12	143	20.3
30-39	6	1	4	20		8	28	8	75	10.6
40-49	1		3	9	2	4	19	2	40	5.6
50-59			3	1	7	10		2	23	3.3
60-69		1		2	3	4	5	3	18	2.6
70-79			1	3	3	4	1	2	14	2.0
80-89				1	2	2	3		7	1.0
90-99					5	9	2	1	5	0.7
100 plus									16	2.3
Total	53	32	61	189	39	81	171	70	750	100.0

For the most part, the busses are operated only on the main highways joining centers of population, where sufficient traffic can be obtained. The feeder or secondary roads do not, in general, lend themselves to this type of common-carrier business. It will be seen, however, that a large percentage of the State highway systems, which include the more important roads, is already covered by motor-bus routes. In four of the eight States, i. e., Arizona, Maryland, Oregon, and Washington, more than half the State highway system mileage is so utilized. In Arizona and Washington, indeed, the motor busses operate over a mileage equivalent to that of the entire State system and a good many miles besides.

TABLE 3.—Relation of motor-bus routes to highway mileage

State	Motor-bus routes	Rural highways	Ratio of bus mileage to rural highway mileage	State highway system	Ratio of bus mileage to mileage of State highway system	State		Railroad mileage	Motor-bus route mileage	Ratio of motor-bus route mileage to railroad mileage
						Miles	Miles			
Connecticut	1,822	12,152	6.8	1,821	45					
New Hampshire	311	13,841	2.2	1,367	23					
West Virginia	987	35,173	2.8	3,594	27					
Kentucky	3,876	68,704	5.6	8,000	48					
Arizona	2,358	21,227	11.1	1,964	119					
Oregon	3,739	45,475	8.2	4,464	84					
Washington	4,379	45,816	9.6	3,133	140					
Maryland	1,622	14,772	11.0	2,247	72					
Total	18,094	257,160	7.0	26,610	68					

<sup>1</sup> This is the net mileage of highways used by motor busses; lines having a total length of 102 miles use highways used by other lines.

Information with regard to the character of the roads used by the busses is available in the records of only two of the States, Connecticut and New Hampshire. In Connecticut 201 miles or 24.4 per cent of the total of 822 miles used are surfaced with concrete; 476 miles or 58 per cent with waterbound macadam; and 145 miles or 17.6 per cent with gravel. In New Hampshire the type of improvement is generally lower. Of what may be called high-type surfaces, including concrete, asphalt, and bituminous macadam, there are only 66 miles, which is less than 22 per cent of the 309 miles classified by type, and only 12 miles or 4 per cent are waterbound macadam; whereas 190 miles or 62 per cent are surfaced with gravel and 41 miles or 13 per cent are unsurfaced earth roads. The Maryland roads, although they are not classified in the records, are known to be of generally high type. As will appear

later in detail, the average rates of fare in these three States are, for Connecticut, 4.6 cents per mile; for New Hampshire, 6.5 cents; and for Maryland, 4.5 cents per mile. To some degree, in all probability, the higher rate charged in New Hampshire may be due to the lower type of road improvement; but such a conclusion can not properly be drawn from the data available because of the differences which exist in the three States with respect to the length of routes and other factors.

#### COMPETITION OF BUSSES WITH RAILROADS

In the eight States in which 18,094 miles of highway are used for the regular operation of common carrier busses, there are only 22,994 miles of railroad. It is apparent, therefore, that, in point of territory served, the bus development is already almost as extensive as that of the railroads. Two States, in fact—Maryland and Oregon—have a mileage of bus routes which exceeds their rail mileage, as shown in Table 4. At the other extreme are the States of West Virginia and New Hampshire, in which the mileage of motor-bus routes is only about one-fourth of the railroad mileage; but, the mileage in these States being relatively small, the average ratio for the eight States is reduced only to 79 per cent.

TABLE 4.—Motor-bus routes and railroad mileage

State	Railroad mileage	Motor-bus route mileage	Ratio of motor-bus route mileage to railroad mileage	Per cent
Connecticut	1,003	1,822	82	
New Hampshire	1,239	311	25	
West Virginia	4,057	987	24	
Kentucky	3,955	3,876	98	
Arizona	2,452	2,358	96	
Oregon	3,347	3,739	111	
Washington	5,494	4,379	80	
Maryland	1,447	1,622	112	
Total	22,994	18,094		

<sup>1</sup> This is the net mileage of highways used by motor busses; lines having a total length of 102 miles use highways used by other lines.

In view of the rapidly growing mileage of the bus routes considerable opposition has been made by steam-railroad operators on the ground that such operations come into direct competition with passenger railroad trains. It is therefore a matter of interest to see what part of the operation actually furnishes a service which competes with that of the railroads. For this purpose, in the States for which the data are available, the various bus routes have been divided into three classes according to the degree to which they enter into competition with the railroads.

Class I includes the routes which parallel the railroads and may therefore be said to come into direct competition with them. Class II includes routes which indirectly compete with railroads to the extent that their terminals are also connected in some manner by railroad, though to travel between the bus terminals by railroad would necessitate change of trains at one or more junctions and a roundabout journey. Finally, Class III includes the routes which, serving territory not served at all by railroad, are wholly noncompetitive. The mileage of the routes in each State which fall

TABLE 5.—*The competition of motor-bus routes with railroads*

State	Class I routes—Directly competitive				Class II routes—Indirectly competitive				Class III routes—Noncompetitive				Total			
	Routes		Length		Routes		Length		Routes		Length		Routes		Length	
	Number	Per cent	Miles	Per cent	Number	Per cent	Miles	Per cent	Number	Per cent	Miles	Per cent	Number	Per cent	Miles	Per cent
Connecticut.....	23	43	463	50	17	32	311	25	150	16	53	100	924	100		
New Hampshire.....	7	22	60	19	6	19	91	30	59	51	32	100	311	100		
West Virginia.....	23	38	282	29	30	49	591	60	8	13	114	11	61	100	987	100
Kentucky.....	70	37	1,588	41	40	21	1,074	28	79	42	1,214	31	189	100	3,876	100
Arizona.....	10	26	728	31	14	36	1,061	45	15	38	569	24	39	100	2,358	100
Oregon.....	31	38	1,916	51	11	14	355	10	39	48	1,468	39	81	100	3,739	100
Washington.....	67	39	1,730	40	40	23	1,123	25	64	38	1,526	35	171	100	4,379	100
Total.....	231	37	6,767	41	158	25	4,606	28	237	38	5,201	31	626	100	16,574	100

within each of these classes is shown in Table 5, together with the percentage of the total in each class.

Considering all routes in seven of the States it will be noted that only slightly more than one-third of the number of routes and 41 per cent of the mileage come into direct competition with the railroads by paralleling rail lines. The routes which directly or indirectly compete with railroads are 62 per cent of the total number and their mileage is 69 per cent of the total mileage. Thirty-eight per cent of the number of routes and 31 per cent of the mileage extend between points one or both of which are not on any line of railroad and are therefore wholly noncompetitive. These 5,201 miles of noncompetitive bus lines constitute an addition to the common-carrier service provided by the railroads equal in mileage to approximately one-fourth of the total railroad mileage in the seven States.

As to the routes which are wholly noncompetitive with the railroads there can be no question, from the point of view of the public, of the propriety of their operation. Their use and the returns from the use will determine in each case whether the operation is feasible from the point of view of the operator. As to the routes of Class II which indirectly compete with the railroads by connecting terminals that are also connected by railroads there may be some ground for question as to the expediency of the operation; but with respect to the routes actually operated it is fair to presume that this question has been investigated and decided on its merits favorably to the bus operators by the public service commission in each case. It is worthy of note that these two classes of routes which either compete not at all or only indirectly with the railroads include 63 per cent of the total number of routes in the eight States, and that their combined mileage is 59 per cent of the total mileage.

In Kentucky there are still 15 counties which do not have any railroad lines. These particular counties are served by 19 motor-bus routes over which 31 busses are operated.

#### THE NEW HAMPSHIRE ABDONMENTS OF BOSTON & MAINE NOT CAUSED BY BUS COMPETITION

Even where the bus line directly parallels a railroad it does not follow from that fact alone that the bus service is not a desirable public convenience. With respect to such bus lines actually in operation there is, indeed, weighty evidence that the service is really desirable in the facts that the operations have been permitted by the public service commissions and that they are able to continue in competition with the railroads.

Considerable interest has been shown in the announced policy of the Boston & Maine Railroad Co. to abandon 1,000 miles of its track. It has been inferred that competition by motor vehicles and motor busses may be partly to blame for the reduced traffic which appears to necessitate the elimination of certain of the rail lines. As a matter of fact, it appears that as far as bus lines are concerned the competition with this railroad is very limited.

Ninety-six miles of the trackage which the railroad desired to abandon is in the State of New Hampshire, one of the eight States under consideration in this article. A special effort has been made, therefore, to ascertain to what extent the abandonment of these 96 miles may have become desirable as a result of motor-bus competition. It is found that none of the mileage proposed for abandonment has to meet any motor-bus competition, either direct or indirect. It can not be claimed, therefore, that motor busses have taken away any of the passenger traffic which these lines formerly enjoyed.

As a matter of fact, only a very small portion of the total railroad mileage in New Hampshire has any motor-bus competition. The total railroad mileage in the State is 1,239 miles; the motor-bus routes which run parallel amount to only 60 miles, or 4.9 per cent. If the routes of Class II are also included as being to a certain extent competitive, we find that there are still only 151 miles of competing bus routes, which is only 12.2 per cent of the total railroad mileage.

#### RELATIVE SERVICE OF COMPETING BUS AND RAIL LINES

As almost invariably the rates charged by the bus operators are higher than the rates of competing railroads, the fact that the bus lines are able to continue in business must be due to some superiority of the service rendered.

With respect to the routes of Class II, this superiority is manifest in more direct routes, lower total charges for service between the terminals, and more frequent service than the railroads are able to offer. Thus the total mileage of the Class II bus lines in Connecticut is 297 miles. The sum of the distances one would have to travel by railroad in going from one terminal to the other of these bus routes would be 610 miles, or a little over twice the length of the bus routes. The total of the motor-bus fares for the travel of 297 miles would be \$14.20, and the railroad fares for the journeys between the same terminal points would total \$21.96, which is 54 per cent greater.

In many cases the Connecticut Class II bus lines materially shorten the distance between two points

which are connected by railroad only in a very round-about way. The most extreme case found is that of the bus route between Torrington and Bantam, over which the distance is 10 miles and the fare 60 cents. Travel between these two points by railroad involves a total distance of 73 miles, with two train changes, at a cost of \$2.63. Another example from Connecticut is the trip from Canton to Collinsville, which is only 2 miles by motor bus and 12 miles by railroad. From Colchester to New London is 20 miles by motor bus, with a fare of \$1; the train between the same two points makes a trip of 66 miles with three changes for a fare of \$2.38.

Where the bus routes parallel the rail lines it will generally be found that the ability of the bus operators to meet the railroad competition is due to the greater frequency of service. Where the time required for the trip and the fares can be compared, the advantages lie wholly with the railroads. Considering all Class I bus routes in Connecticut, the total time consumed in going from terminal to terminal of all the routes amounts to 21 hours and 55 minutes. To make the same trips by railroad passenger trains takes only 18 hours and 40 minutes. The time of the motor-bus journeys exceeds that of the trains by 18 per cent. The total railroad fares would be \$17 and the motor-bus fares \$20.35, or 20 per cent more. The ability of the motor bus to get business under such conditions must be due, therefore, to the more frequent operation and to the more complete service they render by picking up and discharging passengers in the central business districts of the cities through which they pass.

As to the greater frequency of the motor-bus service there is direct evidence in the Connecticut data, which shows that the busses of Class I make 314 trips every day between points served by the railroads with only 190 trips. Each motor-bus route averages 13.7 trips per day; whereas the parallel steam roads average only 8.7 daily trips. According to this, the bus service is 50 per cent more frequent.

In granting permits to operators of motor busses the public service commissions of the several States are inclined to give protection to railroad service where it appears that public necessity does not require the additional service and that the proposed motor-bus service would cut into the much-needed revenues of the rail carrier. Where the railroad service is reasonably frequent and where there is not enough traffic to support more than one mode of transportation, the commissions are generally inclined to oppose the inauguration of the new service. It is the general practice not to allow competition between common carriers; this holds true also where a second motor-bus operator proposes to give service over a route already served by a bus line and where it appears that there is not enough traffic in sight to support the additional service.

#### ATTITUDE OF THE PUBLIC SERVICE COMMISSIONS ILLUSTRATED

The attitude of the public service commissions is illustrated by the findings of the Connecticut commission in the matter of an application to establish a motor-bus line between the cities of Hartford and Meriden. The distance between the two cities is 18 miles. The New York, New Haven & Hartford Railroad Co., operates 19 trains each way on week days

between the two points. The railroad fare is 65 cents and the running time 30 minutes.

It was proposed to operate busses on the highway connecting the two cities, giving hourly service at the same fare charged by the railroad, though the running time was to be 50 minutes. The evidence presented at the time of the hearing disclosed that the railroad carried approximately 300 single-trip passengers daily and 200 commuters. The commuter's fare is about 20 cents. It was pointed out by the commission that the motor-bus line could not take care of this commuter traffic, nor could it meet this low rate of fare. The result of the motor-bus operation would be to take away from the railroad a considerable number of the other passengers and thereby deprive the company of a portion of the revenues produced by the regular fare.

It was feared by the commission that such circumstances would react to the detriment of the commuters favored by the low rates by forcing an increase in their fare and probably leading to a reduction of service. According to the testimony as to public convenience and necessity, it was shown that the only persons urging the establishment of the bus service were those individuals residing along the trunk highway connecting Hartford and Meriden, and not enough prospective traffic was in sight from those sections without the through traffic to warrant the operation. The application was therefore dismissed and the certificate denied.

An analysis of the location of the motor-bus routes in Connecticut shows that there are no bus routes running parallel to steam rail lines over which frequent and well-spaced train service is afforded and where the bus service would cater largely to passenger traffic moving between large centers of population. There are, for instance, no bus lines operating on the Boston Post Road from the New York line to New Haven, except the line operated by the street railway company between New Haven and Bridgeport. There is none between New Haven and Hartford, or between Hartford and Waterbury. In each case it appears that there is frequent and ample steam rail service.

Now and then the commission faces a situation which involves two or more applications on the part of prospective bus operators desiring to give service over a route which the commission is ready to approve. It has then to decide which one of the candidates for a certificate should be favored. In deciding such cases the commission bears in mind the financial responsibilities of the respective applicants, their past records and performance, the general character of equipment and service proposed, and the expressed preference of the people of the communities to be served.

#### MOTOR-BUS FARES

In only three of the eight States was it possible to obtain information relative to motor-bus fares. In Connecticut and Maryland the average rates are approximately 4.5 cents per mile; in New Hampshire, 6.5 cents per mile. As the railroad fare is 3.6 cents per mile, it is clear that people do not ride in motor busses to escape payment of unreasonably high railroad fares; for not only are the regular railroad rates considerably less than the average bus fare, but the former offer to regular riders commutation rates which make the disparity between the average rail rates and bus rates even greater.

The fares charged by all New Hampshire bus lines and by representative lines in Connecticut and Maryland are classified in Table 6. The lowest fare charged by any line in the three States is the rate of 2 cents per mile charged by one line 9.8 miles in length in Maryland. The highest rate is the charge of 18.8 cents per mile on an 8-mile route in New Hampshire. The fares in this State are generally higher than in the other two States and, as shown by Table 6, there are 14 of the routes in the State, or 44 per cent of the total number, that charge higher rates than any charged in either of the other States. The 15-cent rate is charged on a 3-mile route from Sunapee to Sunapee Station, where 45 cents is charged on a 10-passenger bus.

TABLE 6.—*Fares charged by interurban and suburban bus lines in Connecticut, New Hampshire, and Maryland*

Rate of fare per mile (cents)	Connecticut routes		New Hampshire routes		Maryland routes	
	Number	Per cent	Number	Per cent	Number	Per cent
2 to 3	2	4.2	1	3.1	1	3.1
3 to 4	7	14.9	4	12.5	6	18.8
4 to 5	21	44.7	3	9.4	11	34.4
5 to 6	11	23.4	7	21.9	13	40.6
6 to 7	3	6.4	2	6.3	1	3.1
7 to 8	3	6.4	1	3.1		
8 to 9			1	3.1		
9 to 10			4	12.5		
10 to 11			2	6.3		
12 to 13			5	15.6		
15 to 16			1	3.1		
18 to 19			1	3.1		
Total	47	100.0	32	100.0	32	100.0

The lowest rate charged in Connecticut is 2.4 cents per mile, the highest 7.7 cents. The lowest in New Hampshire is 2.5 cents and the highest the 18.8-cent rate referred to above. The lowest in Maryland is the 2-cent rate already mentioned, and the highest rate charged in this State is 6 cents a mile. In Connecticut only 7 out of the 47 routes for which the fare information is available, or 15 per cent, charge fares equal to or less than the standard railroad rate of 3.6 cents per mile. In Maryland 4 of the 32 routes, or 13 per cent, have similarly favorable rates, and approximately the same relative situation exists in New Hampshire.

Although it is evident from the above that the bus lines are not able to meet the railroad rates, a comparison of the rates charged on routes in direct competition with railroads with those charged by the routes which do not have such direct competition indicates in each of the States that the railroad competition does operate to keep the bus fares at a lower level. In Connecticut, for example, the average rate of fare charged by the bus lines which operate on routes that parallel steam railroads is 4.3 cents a mile; on the lines not directly in competition with railroads it is 4.9 cents. In New Hampshire the Class I lines charge an average fare of 4.4 cents a mile, those in Class II charge an average of 5.5 cents, and the Class III lines, which have no rail competition either direct or indirect, charge an average fare of 7.9 cents. It is evident that the actual or potential competition of railroad lines tends to keep the bus fares at a lower level than where such competition is not present.

#### LICENSE FEES AND TAXES VARIABLE

The licenses, special permit fees, and gasoline taxes levied on motor-bus operations vary considerably in the States under consideration. In order to make a

comparison, the following specifications have been taken as a basis for the computation of fees: 20-passenger bus, pneumatic tires, 9,000 pounds weight, 30 horsepower, price \$8,000, 50,000 miles travel annually, \$12,000 gross annual receipts, and 7,142 gallons annual gasoline consumption. Such a vehicle would pay in each of the States the fees and taxes shown in Table 7.

TABLE 7.—*Motor-bus license fees and taxes*

State	Annual license fee	Gasoline tax	Total	Personal- property tax in addition
Connecticut	\$82.50	\$71.42	\$153.92	Yes.
New Hampshire	276.00	142.84	418.84	Yes.
West Virginia	666.67	249.97	916.64	Yes.
Kentucky	270.00	214.26	484.26	Yes.
Arizona	25.00	214.26	239.26	No data.
Oregon	177.00	214.26	391.26	No.
Washington	250.00	142.84	392.84	Yes.
Maryland	1,428.57	142.84	1,571.41	Yes.
Average	396.96	174.09	571.05	-----

As in six of the seven States for which information is available personal-property taxes are levied upon the busses in addition to the license and gasoline taxes shown in Table 7, these taxes must be considered, in these six States at least, as wholly of the nature of special taxes for the use of the road and comparable directly with the railroad expenditures for maintenance of way. As will be observed, the lowest taxes are levied in Connecticut, the highest in Maryland, and the total tax in Maryland for the assumed vehicle is more than ten times the Connecticut tax. The average tax, \$571.05 for the eight States, is 4.75 per cent of the assumed gross annual receipts of \$12,000.

Under the Maryland law motor-bus operators are required to file reports covering their financial operations for the year. Although much of the data contained in these reports are not, in most cases, presented in accordance with good accounting principles, the items of gross revenues, taxes and licenses, and gasoline and oil expenditures are, in all probability, fairly reported. In their annual reports for 1924, 13 motor-bus operators reported a tax and license expenditure of \$19,932, the same operators showing gross receipts of \$344,587. The taxes and license fees of these operators, therefore, amounted to 5.8 per cent of the total revenues. The range was from 3.7 to 8.2 per cent, but only four exceeded the average.

The largest operator, with 50 busses, had a revenue of \$141,709; the smallest took in but \$1,128 with his Ford touring car which he used as a passenger and mail carrier. Fourteen operators with gross receipts of \$367,934 expended for gasoline and oil, according to their reports, \$52,704, or 14.3 per cent of their total revenues. The ratio of gas and oil expenditures to revenues ranged from 8.6 to 30.5 per cent. The latter figure, however, was unusual, and the next below it was 20 per cent. It would be a fair generalization to say that the gasoline and oil costs were from 10 to 20 per cent of the passenger receipts.

#### THE CAPACITY OF BUSSES IN USE

Over a third of the common carriers classified in this analysis as busses are five and seven passenger touring cars. In fact, three of the vehicles so classed in Kentucky have accommodations for less than five passengers, the smallest being a one-passenger vehicle.

The type of vehicle generally termed a "bus" is first encountered in the 8 to 14 passenger group. The vehicles of this type, carrying eight passengers and more number, in the seven States for which the information is obtainable, 923 and comprise 64.6 per cent of the total number of common carriers in these States. The large busses of 25 passengers capacity and over constitute only 5.1 per cent of the total number.

A summary of the capacity of the busses in operation is presented in Table 8, from which it will be seen that the 1 to 7 passenger group comprises 35.4 per cent of the total number; the 8 to 14 passenger group 25.3 per cent; the 15 to 24 passenger group 34.2 per cent; and the 25 passenger class 5.1 per cent as stated above.

TABLE 8.—Classification of interurban and suburban motor busses according to capacity

State	Number of busses of various capacities				
	1 to 7 passengers	8 to 14 passengers	15 to 24 passengers	25 passengers and over	Total
Connecticut.....	40	30	77	21	168
New Hampshire.....	12	18	14	—	44
West Virginia.....	91	14	43	1	149
Kentucky.....	148	70	51	1	270
Arizona.....	62	10	17	3	92
Oregon <sup>1</sup> .....	—	—	—	—	—
Washington.....	147	173	191	35	546
Maryland.....	7	47	96	11	161
Total.....	507	362	489	72	1,430

<sup>1</sup> Capacity data lacking.

The 168 busses operating on interurban routes in Connecticut have an average capacity of 16.3 passengers. In this State there is apparently no marked tendency to confine certain types of vehicles to the short or long routes. The 20-passenger bus is found on both the short and long routes. The seven-passenger car is also found on the various routes up to 30 miles in length. It is evident in this State that the capacity of the bus is adjusted to the demands of traffic regardless of the length of the route.

In New Hampshire the average seating capacity of the busses is 12.8 passengers; and the most popular sizes are the 5, 14, and 20-passenger vehicles of which there are, respectively, 9, 8, and 7 vehicles each among the total of 44 busses operating in the State.

In West Virginia the average capacity is only 9.9 passengers and the predominant sizes among the 149 busses in operation are the 5, 7, and 16-passenger types, of which there are, respectively, 22, 69, and 22 busses. Over 61 per cent of the busses in this State are five and seven passenger touring cars.

Kentucky which, next to Washington, has the largest number of busses in operation, has, next to Arizona, the smallest average seating capacity per bus. The average is 9.7 passengers. Over half the so-called busses are of seven-passenger capacity or less, and a third are of small capacity, ranging from 8 to 15 passengers each. The larger busses, seating from 16 to 26 passengers, comprise only 12 per cent of the total number.

Arizona, in which the average capacity of the busses is only 9.6 passengers, has a larger percentage of the touring-car busses than any other State analyzed. Only 32.3 per cent of the vehicles in this State are of the strictly bus type.

#### CLASS III ROUTES IN OREGON HAVE SMALL CAPACITY

Although a complete classification of the busses in Oregon according to capacity is not possible, the data show that the average seating capacity of the 310 busses in operation is 12.9 passengers. It follows, therefore, that a large number of the busses in operation must be of the larger sizes. In this State the records show that the busses operating on Class I routes, which parallel rail lines, have an average seating capacity of 16 passengers; those operating on the Class II routes, indirectly in competition with railroads, have an average seating capacity of 11.5 passengers; and those operating on Class III routes, which do not compete at all with the railroads, seat an average of only 8.1 passengers. It is apparent that the carriers in this State operating on routes leading off from the railroads are of relatively small capacity. Although the Class III routes constitute 48.2 per cent of all routes, the capacity of the busses operating on these routes is only 20 per cent of the total bus capacity on all routes in the State.

There are 546 busses in operation in Washington, more than in any of the other States, and these busses have a total seating capacity of 7,771 passengers, equivalent to that of 111 railroad passenger coaches with seats for 70 passengers each. The average capacity of the Washington busses is 14.2 passengers. Although the seven-passenger touring car, of which there are 116, is used more than any other size, 53 per cent of the vehicles fall within the capacity group of 10 to 19 passengers. Eighty-two per cent have a passenger capacity of less than 20.

A comparison of the Maryland records for 1924 and 1925 shows that, although the number of busses in operation increased from 106 to 161, the relative number of vehicles of the several capacity classes did not change materially. The classification in Table 9 shows that the 8 to 14 passenger group increased both in number and percentage more than any other group. The only other group to increase in percentage was the 21 to 28 passenger group; both the 5 to 7 and the 15 to 20 passenger vehicles falling off in percentage although they increased in numbers. The increase in the number of large-capacity busses, those of 20 passengers and over, is partially accounted for by the inauguration of bus service between Baltimore and Washington and between several other large cities.

TABLE 9.—The capacity of Maryland busses in 1924 and 1925

Capacity	Busses operating in 1924		Busses operating in 1925	
	Number	Per cent	Number	Per cent
5-7 passengers.....	5	4.7	7	4.3
8-14 passengers.....	26	24.5	47	29.2
15-20 passengers.....	53	50.0	70	43.5
21-28 passengers.....	22	20.8	37	23.0
Total.....	106	100.0	161	100.0

#### INTERSTATE BUS OPERATION

Of the 53 interurban motor-bus routes authorized by the Public Utilities Commission of Connecticut, 10 routes, or 19 per cent, are interstate in character. Two routes extend into the State of New York, five extend into Massachusetts, and three into Rhode Island. It is reported that there are other lines engaged in interstate operation, the operators of which deny the jurisdiction of the Connecticut commission on the ground that they carry passengers in interstate commerce only.

In recent decisions of the United States Supreme Court in the cases of *Bush v. Public Service Commission of Maryland*, No. 185, Mar. 2, 1925, and *Bush v. Kuykendall*, No. 345, Mar. 2, 1925, the court held in effect that the State public service commissions may not prohibit the operation of busses engaged exclusively in interstate commerce by withholding a certificate of public convenience and necessity; although the court held that the inhibition in this respect does not prevent the States from demanding full compliance with all State laws and regulations with respect to the use of the road designed to preserve the roads and promote the safety of road users.

Nine of the 61 routes in West Virginia, or nearly 15 per cent, are interstate routes; 14 of the 189 routes in Kentucky, or 7.4 per cent, are similarly classed; and 7, or 3.7 per cent, of the 189 routes in Washington are also interstate. The exact number of interstate routes in the other States is not available. There are several in Maryland, the most important of which are the two operating between Baltimore and Washington in the District of Columbia. In Arizona there is one route 340 miles long, which extends from Phoenix to Riverside, Calif.; and in Oregon the longest route in the State is one which extends for 346 miles from Portland south to the Oregon-California line and by its connections with California lines provides what amounts to an interstate service.

#### DAILY TRIPS AND MILEAGE

The available records of Connecticut and New Hampshire provide information with regard to the number of trips made each day by busses operating on routes of various lengths and the bus mileage on the various routes. This information is tabulated in Tables 10, 11, and 12.

TABLE 10.—*Daily trips on bus routes of various length in Connecticut and New Hampshire*

Length of route (miles)	Connecticut		New Hampshire	
	Number of daily trips	Per cent	Number of daily trips	Per cent
0-5	78	11.6	182	64.5
5-10	218	32.4	48	17.1
10-15	62	9.2	44	15.6
15-20	26	3.9	4	1.4
20-25	148	22.0		
25-30	72	10.8		
30-35	48	7.1	2	.7
35-40	16	2.4		
45-50	4	.6		
60-65			2	.7
Total	672	100.0	282	100.0

TABLE 11.—*Classification of Connecticut routes according to daily bus mileage*

Daily bus mileage	Routes	
	Number	Per cent
0-100	14	26
100-200	23	44
200-300	6	11
300-400	6	11
400-500	2	4
500-600	2	4

TABLE 12.—*Daily bus mileage on routes of various lengths in New Hampshire*

Length of route	Daily bus mileage	
	Miles	Per cent
0-5	582	34
5-10	318	19
10-15	536	32
15-20	76	4
20-25	64	4
25-30	120	7
30-35		
35-40		
40-45		
45-50		
50-55		
55-60		
60-65		
Total	1,696	100

The largest numbers of daily trips in both States are made on routes of 10 miles or less in length. In Connecticut 51 per cent of all routes are less than 20 miles long and the trips made over these routes are 57 per cent of the total number of daily trips made in the State. In New Hampshire, where the routes are even shorter than in Connecticut, 64.5 per cent of the total number of daily trips are made on routes less than 5 miles in length.

In Connecticut the daily bus mileage on 70 per cent of the routes is less than 200 miles, and 26 per cent have a daily mileage of less than 100. Two routes—those between New Haven and Waterbury and Bridgeport and Waterbury—by reason of the frequency of the service have an extraordinarily large daily mileage. On the New Haven-Waterbury route, 24 miles in length, there are 34 single trips a day and a daily operation of 816 bus-miles. On the Bridgeport-Waterbury route, 30 miles long, there are 28 single trips daily resulting in a daily operation of 840 bus-miles. The published time schedules of the various operators in this State show that additional trips are made over many of the routes on Saturdays, Sundays, and holidays. It may safely be said that the bus mileage on these days is from 10 to 20 per cent higher than on ordinary week days.

#### INDIVIDUALS AND PARTNERSHIPS CONTROL MAJORITY OF ROUTES

The operation of the majority of the routes in most of the States is in the hands of individuals or partnerships, most of which operate only one or two vehicles. In all States, however, corporations have entered the field, and, as would be expected, these organizations operate a greater number of vehicles. In one of the States, Maryland, there is a corporation which operates 50 or more busses over a number of routes, but that is exceptional. The certificate of convenience and necessity required by law protects the small operator so long as he serves the transportation needs of the public in a satisfactory and adequate manner, and tends to preserve the small-scale operation.

Sixty-three per cent of the operators in Connecticut are individuals who control 61 per cent of the total number of routes, but operate only 34 per cent of the total number of busses. Contrasted with this, the corporations in the State, which constitute only 29 per cent of the number of operators, control 31 per cent of the routes and operate 60 per cent of the busses. Partnerships in this State constitute 8 per cent of the number of operators, control 8 per cent of the routes, and operate 6 per cent of the busses.

(Continued on page 232)

# EFFICIENCY IN CONCRETE ROAD CONSTRUCTION

A REPORT OF OBSERVATIONS MADE ON GOING PROJECTS BY THE DIVISION OF CONTROL,  
BUREAU OF PUBLIC ROADS

Reported by J. L. HARRISON, Highway Engineer

## PART II.—THE TRANSPORTATION OF MATERIALS

**I**N THE first article of this series, special attention was given to the causes generating delay at the mixer because the mixer is the pacemaker for the job. Slow operation of the mixer must be corrected at the mixer, but other causes of delay point back into the underlying organization, and their correction involves a study of the other parts of the organization and their relation to each other. A concrete paving organization is composed of a number of units which, for efficiency, must be synchronized. If the mixer is to turn out 1,000 feet of paving every day, the sub-grade gang must prepare that amount of subgrade every day, the form setters must set 1,000 feet of forms, the railroad must deliver the materials for that quantity of concrete every day, the batcher plant must handle it, the trucks must haul it, the finisher must finish it, and the water supply must be adequate to mix it and to cure it. There must be a smooth consistency of progress in all of these operations—no running ahead, no lagging behind. In short, every part of the construction machine must be in balance with every other part—each maintaining an even, steady pace and all gauged to fit the pacemaker, the mixer.

But when the causes of low production are measured at the mixer and analyzed as in the first of this series of articles, it generally develops that some, at least, of the delays, though expressed in such simple terms as truck shortage, inadequate water supply, waiting for sub-grade, etc., point to basic and often far-reaching lack of balance in the organization, the result of failure to appreciate that a concrete construction organization is really composed of a number of smaller organizations each of which, in size and equipment, must be gauged by the production it is desired to obtain from the mixer organization. This is outstandingly true of the transportation, which is not surprising, for the problem of balancing the delivery of materials to the mixer so as to maintain full-capacity output is not always a simple one, and every new job offers a new transportation problem.

Aside from central mixing plant operation which is not touched upon in this series of articles, the three recognized systems of material delivery are:

1. Delivery by batch trucks from the material yard to the mixer, each batch being dumped directly into the skip.

2. Delivery by industrial railway from the material yard to the mixer, each batch in a separate batch box which, at the mixer, is lifted from the cars by a crane so that its contents may be deposited either in the skip or in an elevated hopper which is a part of the mixer.

3. Delivery by wagons or trucks to the job where the aggregate is deposited in piles along the subgrade and moved to the skip in wheelbarrows.

The use of batch trucks is the method most commonly employed, and the trucks are generally either of single-batch or two-batch capacity. Larger trucks are sometimes seen but are not in common use. The de-

livery problem to-day is, therefore, largely a truck problem, involving, in the first instance, a choice between single-batch and two-batch trucks.

The two-batch trucks are generally either of the heavy-duty or high-speed type. Those of single-batch capacity are almost exclusively of the planetary-transmission type and, with the modifications in transmission now very generally made in the interest of service under excessive load, and a dump body satisfactory for this sort of work, they cost the contractor about \$750 each. Heavy-duty and high-speed trucks, equipped to carry two batches, cost from \$4,000 to \$5,000. The heavy-duty, two-batch truck is generally rated for service at an average speed of about 12 miles an hour; the single-batch truck at an average speed of 15 miles an hour; and the high-speed truck at an average speed of from 18 to 20 miles an hour. These speeds may also be expressed as 5 minutes per mile for heavy-duty trucks, 4 minutes per mile for single-batch trucks, and 3 minutes per mile for high-speed, two-batch trucks, the time for a round trip (1 mile out and 1 mile back) being twice that for 1 mile. Field studies show that actual operating speeds agree, in a general way, with these rated speeds. Occasionally an effort is made to run trucks faster than the speed for which they are designed. This increases the loads delivered per hour but wears out the trucks, increasing depreciation as well as lost time awaiting repairs and the cost of the repairs.

### ESTIMATING THE NUMBER OF TRUCKS REQUIRED

The field studies show that in the operation of a single-batch truck four minutes are needed to cover servicing at a well-equipped material plant and at the mixer while for a two-batch truck six minutes are required. These servicing operations are: (1) Loading sand and coarse aggregate, (2) loading cement, (3) turning on the turntable, and (4) discharging at the mixer. To the time required for these operations there must generally be added about one minute for unavoidable delays, and the total time as given above includes this allowance.

There result, then, the three following formulas which may be used in determining the time required per trip for each of the standard types of trucks:

For heavy-duty, two-batch trucks,  $T = 10d + 6$  ..... (1)

For ordinary single-batch trucks,  $T = 8d + 4$  ..... (2)

For high-speed, two-batch trucks,  $T = 6d + 6$  ..... (3)

in which  $T$  is the time in minutes required for a round trip, and  $d$  is the distance in miles from the batcher plant to the mixer.

For example, if the haul is 2.6 miles, how many trucks of each of the above types would be necessary in order to provide a full supply of material for a mixer, operating at 100 per cent efficiency, the working day being 10 hours?

Solution: Batches required, 48 batches per hour for 10 hours = 480 batches. Working day, 10 times 60 = 600 minutes.

TABLE 1.—*Stop-watch record of truck operation under very lax supervision*

Time: August 21, 1925. Number of single-batch trucks: 20. Condition of route: Good except for some soft spots. Distance loading bins to cement shed: 300 feet. Trucks turn through forms 150 feet from mixer. Haul distance plant to mixer: 1.1 miles.

Truck No.	Delay at plant	Time required to load cement and aggregates	Travel time loaded	Speed loaded	Delay at site of paving	Turning and dumping time	Travel time empty	Speed empty	Total time per round trip
	Min. Sec.	Min. Sec.	Min. Sec.	Mi. p. hr.	Min. Sec.	Min. Sec.	Mi. p. hr.	Min. Sec.	
6.....	1 26	1 34	9 30	10.1	0 30	1 30	7 00	13.7	21 30
16.....	1 22	1 38	9 00	10.7	1 00	1 30	6 30	14.8	21 00
13.....	2 21	1 39	9 00	10.7	1 00	1 30	7 30	12.8	23 00
20.....	3 23	1 37	8 00	12.0	1 30	1 30	7 00	13.7	23 00
7.....	4 04	1 26	7 30	12.8	1 30	1 30	6 00	16.0	22 00
27.....	3 21	2 09	8 30	11.3	1 00	1 30	7 30	12.8	24 00
11.....	3 04	1 26	8 30	11.3	3 00	1 30	5 30	17.4	23 00
28.....	2 19	1 41	11 30	8.4	2 00	1 30	25 00	3.8	44 00
3.....	2 52	1 38	7 30	12.8	2 00	1 30	6 30	14.8	22 00
12.....	3 22	1 38	8 00	12.0	1 30	1 30	9 30	10.1	23 30
25.....	2 35	1 55	12 30	7.7	2 00	1 30	7 30	12.8	28 00
5.....	3 24	1 36	8 00	12.0	2 00	1 30	7 30	12.8	24 00
17.....	1 54	2 06	7 30	12.8	2 30	1 30	6 00	16.0	21 30
23.....	3 10	1 20	8 00	12.0	2 00	1 30	6 30	14.8	22 30
6.....	1 27	1 33	8 00	12.0	0 30	1 30	7 00	13.7	20 00
1.....	1 49	1 41	7 30	12.8	1 30	1 30	6 00	16.0	20 00
19.....	2 01	1 29	7 30	12.8	0 30	1 30	9 30	10.1	22 30
15.....	1 40	1 20	9 00	10.7	0 30	1 30	7 30	12.8	21 30
13.....	1 09	2 21	23 00	4.2	3 30	1 30	8 00	12.0	39 30
7.....	2 59	1 31	6 00	16.0	0 00	1 30	5 00	19.2	17 00
20.....	3 09	2 21	11 30	8.4	6 30	1 30	8 00	12.0	33 00
27.....	2 16	1 44	8 00	12.0	0 00	1 30	8 30	11.3	22 00
11.....	1 31	2 59	7 30	12.8	6 30	1 30	7 00	13.7	27 00
3.....	0 48	3 42	7 30	12.8	6 00	1 30	7 00	13.7	26 30
12.....	1 27	1 33	11 30	8.4	1 30	1 30	29 00	3.3	46 30
23.....	2 15	1 45	9 00	10.7	2 30	1 30	8 00	12.0	25 00
25.....	1 42	1 48	11 30	8.4	4 00	1 30	8 30	11.3	29 00
6.....	2 33	1 27	6 30	14.8	3 00	1 30	8 00	12.0	23 00
16.....	2 16	1 44	7 00	13.7	3 30	1 30	7 30	12.8	23 30
7.....	1 56	1 34	7 00	13.7	4 00	1 30	5 30	17.4	21 30
2.....	1 51	2 09	11 00	8.7	1 00	1 30	11 30	8.4	29 00
Average.....	2 18	1 48	9 06	10.5	2 12	1 30	8 37	11.1	25 31

NOTE.—The slowness of the trucks is in part due to the subgrade but much more to the fact that they are all individually owned. The drivers are responsible for their repairs and the lack of a central repair shop for trucks and the general disorganization due to the trucks not being under one management is reflected in the greater time lost and the greater time required for the various operations.

TABLE 2.—*Stop-watch record of truck operation under efficient supervision*

Time: July 31, 1925. Number of single-batch trucks: 12. Condition of route: Good. Distance turntable to mixer: 200 feet. Distance batcher to cement shed: 500 feet. Haul distance plant to mixer: 1.1 miles.

Truck No.	Delay at plant	Time required to load sand and gravel	Time required to load, dump, and cover cement	Travel time loaded	Speed loaded	Delay at site of paving	Time required to turn on turntable	Time required to dump load	Travel time empty	Speed empty	Total time per round trip
	Min. sec.	Min. sec.	Min. sec.	Min. sec.	Mi. p. hr.	Min. sec.	Min. sec.	Min. sec.	Mi. p. hr.	Min. sec.	
17.....	0 00	0 16	0 35	5 00	13.2	2 30	0 15	0 10	5 00	13.2	13 46
30.....	1 00	0 16	0 35	5 00	13.2	2 30	0 20	0 09	5 00	13.2	14 50
19.....	1 00	0 11	0 42	6 00	11.0	1 00	0 30	0 10	5 00	13.2	14 33
18D.....	0 00	0 11	0 41	4 00	16.5	3 00	0 15	0 07	4 00	16.5	12 14
10.....	0 30	0 20	0 53	4 00	16.5	3 00	0 30	0 10	4 00	16.5	13 23
15.....	1 00	0 10	0 47	5 00	13.2	2 00	0 28	0 06	4 00	16.5	13 31
4.....	1 00	0 20	0 37	5 30	12.0	2 30	0 21	0 06	4 30	14.7	14 54
14.....	2 00	0 14	0 32	5 00	13.2	2 00	0 23	0 08	4 30	14.7	14 47
17D.....	2 00	0 14	0 51	4 00	16.5	2 30	0 18	0 08	4 00	16.5	14 01
8.....	1 00	0 16	0 40	4 00	16.5	2 30	0 17	0 09	5 00	13.2	13 52
7.....	0 30	0 20	1 00	4 00	16.5	2 00	0 19	0 09	5 30	12.0	13 48
32.....	0 30	0 11	0 55	5 00	13.2	2 30	0 26	0 07	4 00	16.5	13 39
17.....	0 00	0 26	0 45	5 00	13.2	2 00	0 24	0 11	4 00	16.5	12 46
30.....	0 00	0 11	0 45	5 00	13.2	3 00	0 32	0 07	4 00	16.5	13 35
19.....	0 30	0 14	0 52	4 30	14.7	2 30	0 18	0 11	5 30	12.0	14 35
18D.....	1 00	0 12	0 37	4 00	16.5	3 00	0 26	0 07	5 00	13.2	14 21
10.....	0 00	0 14	0 42	5 00	13.2	2 00	0 22	0 09	5 00	13.2	13 27
15.....	0 00	0 17	0 55	4 30	14.7	4 00	0 26	0 07	4 00	16.5	14 15
4.....	0 00	0 18	0 38	4 30	14.7	1 00	0 28	0 11	4 00	16.5	11 05
14.....	1 00	0 14	0 44	4 00	16.5	1 30	0 26	0 09	4 30	14.7	12 33
17D.....	1 00	0 13	0 51	3 30	18.8	3 00	0 25	0 11	4 00	16.5	13 10
12.....	0 00	0 10	0 48	5 30	12.0	3 30	0 20	0 09	5 00	13.2	12 27
8.....	0 00	0 16	0 42	5 00	13.3	3 00	0 31	0 11	5 00	13.2	12 10
32.....	1 30	0 16	0 56	4 00	16.5	1 00	0 17	0 08	4 30	14.7	12 37
1.....	0 30	0 15	0 48	4 00	16.5	2 00	0 25	0 11	4 30	14.7	12 39
17.....	0 30	0 13	0 51	5 30	12.0	0 00	0 24	0 13	5 00	13.2	12 41
30.....	0 00	0 10	0 53	5 00	13.2	0 30	0 24	0 08	5 00	13.2	12 05
19.....	1 00	0 14	0 42	5 00	13.2	1 00	0 26	0 11	4 00	16.5	12 33
18D.....	2 00	0 20	0 36	4 00	16.5	1 00	0 29	0 09	4 00	16.5	12 34
10.....	2 00	0 16	0 45	4 00	16.5	1 00	0 32	0 11	5 00	13.2	13 44
15.....	2 00	0 18	0 51	4 00	16.5	2 00	0 31	0 10	4 00	16.5	13 50
Average.....	0 45	0 15	0 45	4 36	14.4	1 55	0 24	0 09	4 32	14.5	13 21

NOTE.—On this date a 125 per cent truck supply was used to eliminate delays at the mixer, because of subgrade operations. This oversupply of trucks accounts for the delays at the plant and at the site of paving. No unnecessary delays occurred at either plant or site of paving.

For two-batch heavy-duty trucks (formula 1)	For ordinary single-batch trucks (formula 2)	For two-batch high-speed trucks (formula 3)
$10 \times 2.6 = 26$ 6	$8 \times 2.6 = 20.8$ 4	$6 \times 2.6 = 15.6$ 6
Time per trip 32 minutes.	Time per trip 24.8 minutes.	Time per trip 21.6 minutes.
$600 \div 32 = 18$ trips. $18 \times 2 = 36$ batches per truck. $480 \div 36 = 13.3$ .	$600 \div 24.8 = 24$ trips. $27 \times 2 = 54$ batches per truck. $480 \div 24 = 20$ trucks.	$600 \div 21.6 = 27$ trips. $27 \times 2 = 54$ batches per truck. $480 \div 21.6 = 8.8$ trucks.
As over 13 trucks are needed, 14 would be required for full delivery.		As over 8 trucks are needed, 9 would be required for full delivery.

Under field conditions heavy-duty trucks sometimes are speeded up a little and operated at a rate for which the corresponding formula is:

$$T = 9d + 6 \quad (4)$$

This is not to be recommended, but is referred to because of the fact that it is a rather common practice and because, where it is done, it affects the number of trucks needed in order to meet specific haul requirements. With high-speed trucks the reverse is true. They are seldom, in practice, operated at a speed averaging over 17 or 18 miles an hour, which results in the approximate formula:

$$T = 7d + 6 \quad (5)$$

Slow speed generally results from the fact that the road between the batcher plant and the mixer is commonly in such condition that higher speeds are out of the question. It is a matter of observation that contractors pay too little attention to the condition of the roads over which their trucks are operated. These are very often earth roads and heavy hauling naturally causes ruts and chuck holes. High speed, even a moderate speed, can be safely maintained only when the roads are reasonably smooth. To obtain full efficiency from the trucks available, therefore, requires that the roads be kept in the best possible condition, and this in turn requires that the provisions for road maintenance be at least as complete as any State or municipality would provide in caring for the more important roads of this type under its jurisdiction.

#### THE COST OF POOR ROADS

Perhaps the clearest way of presenting the financial aspects of this matter is to refer again to the fact that on a standard (5-bag) concrete paving operation the daily pay roll is likely to be in the neighborhood of \$200 and the daily depreciation charge at least half as much. Time, therefore, costs the contractor about 50 cents a minute. If, then, the condition of the roads is allowed to become so bad that full efficiency can not be had from the trucks, and no extra trucks are available to make up this deficiency, there is, in addition to the direct increase in the cost of hauling, the indirect cost which results from slowing down the job as a whole—often the more important loss of the two.

Take, as an illustration, a job where the regular rate of output is 40 batches per hour. If 20 single-batch trucks are available and should, with full efficiency, deliver 40 batches an hour, but because of road conditions can only deliver 32 batches an hour, it is apparent that the cost of hauling has been increased 25 per cent. But, in addition to this, the mixer output has been reduced from 83.33 to 66.66 per cent of full production, a net loss of 16.67 per cent of the day, or 100 minutes,

which, at the rate of 50 cents a minute, costs the contractor about \$50 for every day during which these conditions persist.

Losses of this order are by no means uncommon though perhaps not the rule. Such as do occur, however, are commonly large enough to warrant a contractor in keeping a light grader and team at work whenever it is possible to use it to any advantage. Nor should the fact that the hauling has been sublet constitute in his mind an argument against providing this equipment and doing this work, for, as is clearly shown above, his indirect loss from slow delivery of material may easily exceed the subcontractor's direct loss from low truck efficiency and high repair costs.

The operation of a good road maintainer would hardly cost the contractor more than from \$6 to \$8 a day and ordinarily the whole time of this outfit would not be required in maintaining the roads. Therefore, whenever slow delivery of materials due to the condition of the roads causes loss of time at the mixer which exceeds from 12 to 16 minutes a day, giving attention to the condition of the roads is likely to prove profitable even though all hauling equipment is owned by a subcontractor. Where the delivery equipment is owned by the contractor, the reduced depreciation and repair costs which result from operation over smooth roads alone justify the cost of road maintenance and should dictate that it receive careful attention without regard to any other consideration.

#### SLOW DRIVING A PROMINENT CAUSE OF INEFFICIENCY

In developing the above formulas for trip time no account has been taken of the miscellaneous losses that are often noted in the operation of trucks. Table 1 is a partial study of one job which illustrates how low the efficiency of operation may drop when the supervision is weak. This loss of efficiency results from all sorts of causes, one of the most common being the interest which is taken in the repair of minor defects whenever it is learned that this excuse may make it possible for the drivers to avoid an honest day's work. Positive "hiding out" along the route is uncommon, though not unknown, but the number of little things that can be done to delay matters—a few seconds here, a few there—is surprising. None of these, however, is as effective in reducing efficiency as the driver who deliberately reduces his speed, thereby causing trucks to pile up behind him. If high efficiency is to be secured in the operation of the trucks, it is imperative that drivers be taught to drive the course in the proper time. For an occasional driver to drive faster than the established rate increases wear and tear on his truck and causes confusion without producing any corresponding advantage. To drive below the standard time causes delay.

On most jobs there are four points where the trucks stop—(1) the aggregate bins, (2) the cement sheds, (3) the turntable, and (4) the mixer. Ordinarily from a quarter of a minute to a minute is required in passing any of these four points. If then, by reason of the slow driving of one truck, the pace has been so reduced that four or five trucks arrive at the loading plant in a string, all but the first will be delayed in loading. Take a specific example, involving a 10-minute return trip, and operation at the mixer at the rate of 40 batches an hour, or one batch every  $1\frac{1}{2}$  minutes. Suppose the

TABLE 3.—*Stop-watch record of operation of eight two-batch trucks<sup>1</sup>*

Loading sand and stone	Loading cement	Turning at mixer	Dumping 2 batches	Total time required to turn, load, and dump
Min. Sec.	Min. Sec.	Min. Sec.	Min. Sec.	Min. Sec.
1 20	0 40	1 28	2 39	6 7
1 30	0 30	0 50	2 10	5 0
1 18	0 33	0 50	2 17	4 58
1 3	0 30	0 50	2 40	5 3
1 20	0 28	0 42	2 20	4 50
1 16	0 25	0 55	2 21	4 57
1 0	0 45	0 27	2 4	5 16
<sup>2</sup> 1 15	0 33	1 0	2 22	5 10

<sup>1</sup> Each entry is the average of 10 field readings. The readings show only the time consumed in the actual performance of the operations and do not include any of the various minor miscellaneous time losses indirectly associated with these operations and which can hardly be kept below a total of 1 minute per trip for this class of trucks.

<sup>2</sup> Average.

TABLE 4.—*Stop-watch record of operation of five two-batch trucks<sup>1</sup>*

Loading sand and stone	Loading cement	Turning at mixer	Dumping 2 batches	Total time required to turn, load, and dump
Min. Sec.	Min. Sec.	Min. Sec.	Min. Sec.	Min. Sec.
1 12	1 2	0 50	1 40	4 50
1 28	1 0	0 41	2 4	5 13
1 10	0 58	0 50	2 10	5 8
0 58	1 4	0 45	1 25	4 12
1 17	0 54	0 40	2 9	5 0
1 0	0 55	0 53	2 7	4 55
<sup>2</sup> 1 11	0 58	0 47	1 57	4 53

<sup>1</sup> Each entry is the average of 10 field readings. The readings show only the time consumed in the actual performance of the operations and do not include any of the various minor miscellaneous time losses indirectly associated with these operations and which can hardly be kept below a total of 1 minute per trip for this class of trucks.

<sup>2</sup> Average.

first truck is delayed a minute in its "get-away" from the mixer and is then driven at a rate that will require 14 minutes to make the return trip. When it reaches the cement shed it will be 5 minutes behind schedule. The next truck leaves the mixer promptly, one-half minute after the first, trailing it in. It is, then, 3½ minutes late in arriving, but, because the cement shed can load only one truck a minute, it waits there 1 minute to be loaded and leaves 4½ minutes late. The third truck, catching the first two, trails in with them, arriving 2 minutes late, and is held 2 minutes waiting to be loaded, making it 4 minutes late out of the cement shed. It will be clear without extending the illustration that, as stops occur at the batcher, at the cement shed, at the turntable, and at the mixer, the trucks must be run at a uniform rate and kept at such a distance apart that they will not lose time waiting for service at these points, if high efficiency is to be obtained.

Where trucks tend to run in bunches as above described it usually will be found that once the matter is thoroughly explained to the drivers most of them will cooperate willingly, but a few will consider the matter of no consequence and these should be summarily discharged. It is well worth while to keep a checker at the cement shed, noting time out and time back in such a way that the drivers can know whether they are driving on schedule. Really good drivers will cooperate splendidly if they have this assistance and, with other parts of the job running smoothly, can and will handle the material delivery with the accuracy of a well

administered train schedule. The point is that it is no less difficult to operate material trucks to a mixer on an efficient schedule without supervising assistance than it is to operate trains without a dispatcher. The checker at the material plant should act as a dispatcher and if he has the right personality he can assist materially in keeping the trucks properly spaced and their operation generally as a basis of high efficiency.

A standard time clock can also be used to advantage on this work. Where used, it should be set ahead as many minutes as are required for the round trip. Then by stamping each driver's card as he leaves a fixed point in the circuit (the batcher plant is a satisfactory point) the driver is automatically provided with a printed record showing the exact hour and minute he should be at the batcher again. Moreover, as the card is turned in for restamping the checker can note actual time and gain or lag, so that the driver as well as the superintendent may know whether he is driving correctly or not, and if not, how much he is habitually off schedule.

The one exception to the statement that trucks should be so separated that they can be serviced as fast as they arrive at points where service must be given is found at the mixer itself. Delays at the mixer have been shown to cost the contractor about 50 cents a minute. To avoid delays at this point, therefore, the contractor may well provide something by way of insurance. If the truck supply is just sufficient to feed the mixer, the slightest delay in servicing a truck, the slightest holdup along the line, or any little thing that interferes with the continuous movement of any truck, will cause the mixer to drop a batch. To avoid this, it is desirable to operate an extra truck if two-batch trucks are in use and at least two extra trucks if single-batch trucks are employed. There should also be a stand-by truck on the job ready to run, and all drivers should have orders to abandon disabled trucks at once and return to the loading plant for a new truck, leaving the disabled truck to be taken care of by the regular job mechanics. Finally, where single-batch trucks are used, a 10 per cent surplus should generally be provided to allow for time necessarily lost in the repair shops. With these precautions, lost time chargeable to the trucks can be reduced to an absolute minimum, for it is, indeed, an unusual condition that will throw enough trucks out of use so that the delivery can not be handled by an organization of this sort.

#### THE QUESTION OF THE STAND-BY TRUCK

From the data given above, it is a comparatively simple matter to determine whether the truck supply available on a given job is adequate for the haul prevailing, whether the trucks in use are being operated efficiently, where losses of time are occurring, etc. But the determination of what truck supply should have been provided in the first place is a very different problem. This involves not only the haul conditions on the job but also the average haul conditions on concrete jobs in the territory where the contractor is working, the possibility of using extra trucks on other work, the cost of owning stand-by equipment, etc. A modern heavy-duty truck, for instance, will cost from \$4,000 to \$5,000. The yearly interest on this sum will mount to perhaps \$300. Dead storage, let us assume, will cost \$100 a year, and taking the truck to and from

the job another \$100. In the nature of the case, these figures are supposititious, for the original cost of trucks varies, interest rates vary and jobs are not all an equal distance from headquarters. However, the contractor who is endeavoring to determine what truck supply he can afford to own will know what these figures are in any individual case. For the moment it may be assumed that they generate a yearly stand-by cost of \$500 for each extra heavy-duty or high-speed truck sent out to the job. To be a profitable investment, there must be reason to assume that the savings likely to develop from having such trucks will cover this charge in addition to depreciation, repairs, operating cost, and a profit while they are in use.

Now, it will be apparent at a glance that while the cost of hauling, when considered as an operation by itself and without reference to overhead, is affected by the efficiency with which it is done, it is not affected by the number of transportation units employed. In other words, if there are 1,000 hours of two-batch truck time involved in a given operation, the hauling cost per truck-hour remains constant whether the work is done in 100 days by 1 truck working 10 hours a day or whether it is done in 10 days by 10 trucks each working 10 hours a day. Moreover it may be reasonably assumed that the returns received from whatever work is done by any truck will pay for depreciation, repair costs, operating charges, etc., and will yield a profit reasonable in view of the time worked. But not all the trucks employed in a concrete paving operation are worked full time. Some are in actual use only a small part of the time, and with respect to each of these there is a short time when the truck is profitably employed and a longer period when it is idle. The question as to the advisability of adding hauling equipment which will be employed only part time resolves itself, then, into a matter of determining whether or not the increased output of the mixer made possible by having such trucks is large enough to cover the stand-by charges and show a profit to the owner sufficient to justify the capital outlay involved.

#### STAND-BY COST PAID BY INCREASED MIXER PRODUCTION

It has been shown that mixer time is worth about 50 cents per minute. Therefore, any saving in mixer time which will, at this rate, exceed the assumed stand-by cost of \$500 a year will render the ownership of stand-by equipment profitable. For example, if having an extra truck will enable the mixer to operate more than 1,000 (\$500 divided by 0.50) minutes when it would otherwise be idle, the payroll and depreciation savings thus effected will offset the truck stand-by charges. As in 1,000 minutes the full production would be 800 batches, any production in excess of this amount made possible by having the extra truck will generate a net saving, and if such a saving may be expected to accrue from year to year, as the natural result of ordinary operation, the desirability of having the extra equipment is apparent. From the theoretical standpoint, therefore, the problem is reduced to the simple one of determining whether an extra truck would increase output more than 800 batches a year. It makes no difference whether these 800 batches are hauled in one working period or in two or three. The question is solely whether the truck will enable the mixer to do the additional amount of work during an ordinary working season.

In practice, trucks sent out as stand-by equipment usually work only on the longest haul, which means

that they will be called into service only for short periods when the haul is long. The analysis will, therefore, be continued on that assumption. Thus a 4-mile haul by heavy-duty, two-batch truck requires 46 minutes (see formula No. 1). At that distance, therefore, such a truck will haul 13 loads per 10-hour day; and as two batches are hauled at each load, the day's haulage will be 26 batches and 31 days' work will be required to haul 800 batches. In a similar manner it can readily be ascertained that 25 days will be required to haul 800 batches when the haul is 3 miles, and 37 days when the haul is 5 miles. If, then, the requirements are commonly such that there will be 25 days' work on a 3-mile haul, or 31 days on a 4-mile haul, or 37 days on a 5-mile haul, the stand-by cost will be covered by savings in pay roll and depreciation costs incident to more intensive operation of the mixer, and if more than this time can be worked a profit accrues. In making this analysis it is assumed, of course, that while at work the truck is making a fair profit, and that while in dead storage it is so well cared for that it does not deteriorate.

The foregoing analysis could be extended to allow for the reduction in total stand-by cost, which should properly be made when a truck is put in service. Thus, trucks used as hauling equipment on concrete highway construction ordinarily must be assumed to earn capital charges, cost of delivery to and from the job, winter storage, and profit for the whole year in addition to depreciation and operating expenses while working within the six to eight months during which they are normally operated. If, then, a truck will have three months' work, it should during that period cover at least half of the stand-by cost noted above, out of normal earnings. There is, however, no need to consider this phase of the matter further or to include it in subsequent calculations, because, as will appear later, it will be reasonably clear that trucks which are to be operated over as long a period as this should be supplied in any event, as otherwise mixer operation would fall to an obviously inefficient point. In the last analysis the real problem is that of determining when the purchase of another truck to cut down losses of time at the mixer ceases to be advisable. When that point is reached the time the truck will work becomes so short that the amount by which the stand-by cost would be offset by the earnings of the truck when actually at work is less than the probable error involved in the calculation of the stand-by cost. For that reason it should be ignored in determining whether another truck is needed.

As already noted, deductions of this sort must, of necessity, be illustrative only. Although the principles involved are constant, their application to the different conditions prevailing on various jobs produces results which vary with the local conditions. One thing, however, stands out clearly enough, namely, that if 31 days' operation on a 4-mile haul will result in savings at the mixer that will pay a year's carrying charges on a truck, there are comparatively few jobs that will not justify full hauling equipment.

The development of this phase of the transportation question from the standpoint of the single-batch truck would be based on a computation of the stand-by cost somewhat as follows:

Interest .....	\$50
Dead storage.....	50
Cost of getting to and from the job.....	100
Annual stand-by cost.....	200

In this case the saving of only 400 minutes of mixer time, i. e., the delivery of 320 extra batches, will offset the stand-by cost. This is equivalent to the delivery to and the utilization by the mixer of the batches that such a truck can haul 3 miles in 15 days, or 4 miles in 19 days, or 5 miles in 23 days (see formula No. 2). For two-batch high-speed trucks the stand-by cost is about the same as for two-batch heavy-duty trucks, but the delivery per day is higher. The purchase of an additional truck is justified (by the method used above) if it can be fully utilized for 16 days on a 3-mile haul, or 20 days on a 4-mile haul, or 24 days on a 5-mile haul (see formula No. 3).

#### CONDITIONS AFFECTING HAUL REQUIREMENTS

With these aspects of the case in mind one naturally turns to the question—What are the ordinary haul requirements on a concrete paving job? Unfortunately sufficient data are not at hand to answer this question as fully as would be desirable. On the jobs which have been studied so far a maximum haul of 5 miles has been found to be rather common and hauls longer than this have been rare. This may, then, be taken as a reasonable basis for a further analysis of the transportation problem, and because there are very few contractors who are able to so completely synchronize the various operations involved in laying a concrete pavement as to obtain consistently an output of more than 40 batches an hour, even under a specification allowing a one-minute mix, this will be used as the basis from which to work. It will, of course, be understood that any analysis such as this must be modified by each contractor who adopts it to meet the best performance he is able to secure.

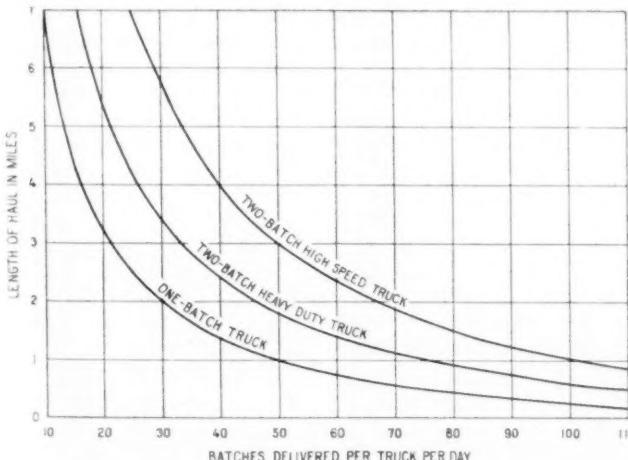


FIG. 1.—Batches delivered per 10-hour day at various haul distances by three types of truck

The mix and the cross section also are factors. Here it will be assumed that one batch (5 bags) yields  $2\frac{1}{4}$  lineal feet of pavement, which means that the output per 10-hour day will be 900 feet. If this rate of production is maintained, a mile of concrete paving will be laid every 5.8 days which, for the purpose of simplifying this discussion, will be called 6 days. A full truck supply for this rate of production (40 batches per hour) for various lengths of haul is, then, as shown in Table 5, which also gives the number of days' work required of a truck in order that savings at the mixer shall offset stand-by cost, the possible

saving due to additional trucks being figured at  $1\frac{1}{4}$  minutes per batch at the mixer. Figures 1 and 2 develop this data in a little different fashion.

TABLE 5.—Number of trucks required and days' work required to offset stand-by cost of various lengths of haul

Haul	Number of trucks required			Number of days' work per truck to offset stand-by cost		
	Heavy-duty	Single-batch	High-speed	Heavy-duty	Single-batch	High-speed
<b>Miles:</b>						
1	6	8	4	11	6	8
2	9	13	6	18	11	12
3	12	19	8	25	15	16
4	15	24	10	31	19	20
5	19	29	12	37	23	24
6	22	35	14	44	27	28
7	25	40	16	50	32	32
8	29	45	18	57	36	36

In the analysis of any specific job, the haul and the required truck supply should be graphed in the manner used in Figures 3, 4, and 5, which were drawn from the

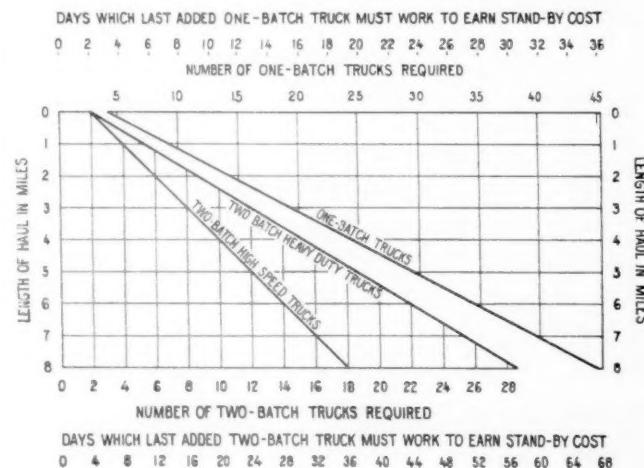


FIG. 2.—Truck requirements for various lengths of haul, and number of days trucks must work at various hauls to earn stand-by cost, with construction at the rate of one mile in six days.

layout data of one of the jobs studied during the past working season. These graphs are drawn to a vertical scale in which one division equals five single-batch trucks and a horizontal scale in which one division equals 1 mile of six days. If any other style of truck is to be used the vertical scale would of course be modified accordingly. In drawing these particular graphs the unit distance scale divisions have been replaced by nonuniform distance and time scale divisions, but this is a minor matter not at all affecting the actual scale used.

To draw a chart of this sort, after selecting appropriate horizontal and vertical scales, first lay off the dead haul, that is, the distance from the plant to the road. Then from Figure 2, determine the minimum number of trucks required to handle the dead haul which determines the minimum truck supply for that set-up. The dead haul distance and the minimum truck supply having been determined and plotted (see fig. 3) the stepped line giving the points at which another truck must be added may be obtained from Figure 2 or calculated from the formula for the distance

over which any given number of trucks can make a full delivery of materials.

The formulas which have been used in developing all of the graphs appearing with this article were derived as follows:

For high-speed, two-batch trucks the time required per load (formula 3) is  $T = 6d + 6$ . As in a 10-hour working day there are 600 minutes.

$L$  (the number of loads hauled per truck per day)

$$\frac{600}{6d+6} \text{ or } \frac{100}{d+1}$$

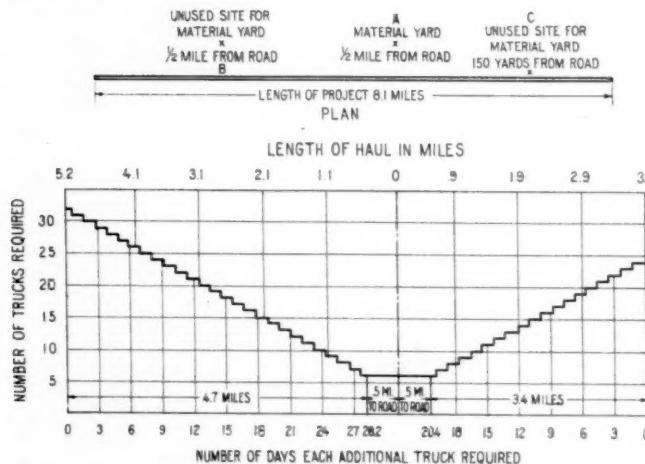


FIG. 3.—Relation of location of material yard to truck supply required. This set-up was actually used by the contractor

If  $N$  equals the number of trucks, the total number of loads delivered during a working day (100 per cent efficiency in truck operation being assumed) becomes  $NL$  or  $N\left(\frac{100}{d+1}\right)$

And as these are two-batch trucks, the number of batches deliverable per day is  $2N\left(\frac{100}{d+1}\right)$

Now let  $Y$  equal the number of batches a day needed in order to meet regular mixer requirements.

Then, if  $Y$  equals  $2N\left(\frac{100}{d+1}\right)$ ; that is, if the total delivery just equals mixer requirements, a solution of the equation for  $d$  will give the maximum distance over which full delivery can be made with any given number of trucks.

In solving this equation the value of  $Y$  is known. For 100 per cent production at the mixer and a one-minute mix, it is 480 batches. Figures 1 to 5, inclusive, were drawn under the assumption that the mixer requirement is 400 batches a day. For any other requirement the graphs would be modified accordingly. In drawing graphs such as those shown, the value of  $N$  will, of course, be varied from the number of trucks required for a zero haul, to the highest number required to obtain full production against the longest haul on the job. In plotting it should be remembered that the solution of this equation gives the longest haul against which delivery at the assumed rate can be made by the assumed truck supply, in other words, the point at which another truck should be added.

This development covers high-speed, two-batch trucks only. A similar development for heavy-duty, two-batch trucks yields the formula  $Y = 2N\left(\frac{300}{5d+3}\right)$

For heavy-duty, five-batch trucks, the formula is  $Y = 5N\left(\frac{300}{5d+7}\right)$  and for single-batch trucks the formula is  $Y = N\left(\frac{150}{2d+1}\right)$

From Figure 2 it is possible to make a further analysis of the stand-by equipment problem. Thus, taking at random one example, a 16-mile job which is to be handled from two plant set-ups, from both of which the haul in each direction will be 4 miles, it is, of course, apparent from the graph for two-batch high-speed trucks that as two trucks are required at zero haul, the third must be added before full delivery of material can take place at any haul beyond the zero point. The minimum truck supply is, therefore, three trucks. These must, of course, remain in service as the haul distance increases, that is, until the maximum distance of 4 miles is reached. But 4 miles in distance has been shown above to be equal to 24 days in time. To perform the work on this 4-mile leg, these trucks must, therefore, work 24 days and as the project is, by the assumption originally made, composed of four such legs, these trucks must perform 96 days work. By a similar process of reasoning the fourth truck, required when the second half of the first mile is reached, will work 84 days, and of the two additional trucks needed to make full delivery over the next mile, one will work 72 days and one 60 days. The next two trucks will work 48 and 36 days respectively. The number of days each of these trucks will be employed is so large that, under the assumption made, there is no question that a profit will be obtained from their ownership. The real problem arises in connection with the next two trucks, those needed to secure full delivery only against the 3 to 4-mile haul. Theoretically one of these will have 24 days' work to do and the other only 12. Of the time worked by the first, 18

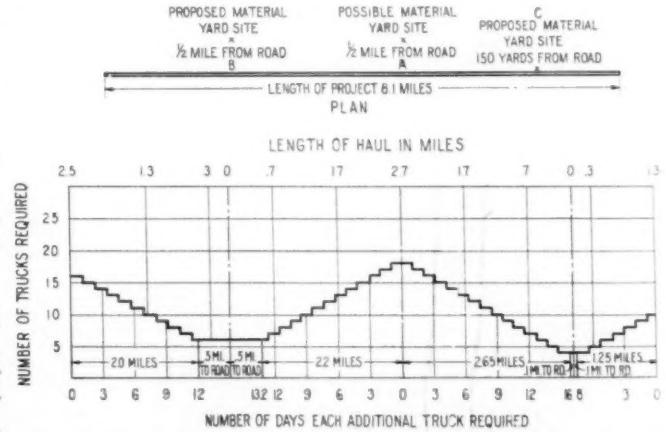


FIG. 4.—Relation of location of material yard to truck supply required (see figs. 3 and 5). If the contractor had hauled from sites B and C the cost would have been less than the cost of hauling from site A only, but more than if he had hauled from all three sites

days will be required to offset stand-by cost, and for the same purpose 20 days' work would be required of the second. Without these trucks, the mixer efficiency would be reduced from 100 per cent at the end of the third mile to 80 per cent at the end of the fourth. If neither of these last two trucks is provided, therefore, the pay roll and depreciation losses could not exceed an average of 10 per cent, or \$30 a day, over the period of 26.6 days which the work would require at the reduced efficiency—a loss of only \$800.

If one truck is purchased, pay roll and depreciation losses would be reduced to an average of 5 per cent, or \$15 a day, over a period of about 12.6 days—about \$190. On this job, therefore, the ninth truck would produce a saving of \$610, against which there must be charged stand-by cost of \$500, a net saving of \$110; while the purchase of the tenth truck would save \$190, against which there would be the same stand-by cost of \$500, a net loss of \$310.

If these were the only considerations, the answer would be clear; the tenth truck would not be justified, and the ninth, while justified, would not earn enough to encourage a contractor to own it unless he has ample resources. But these are not the only matters involved. Probably a more important consideration is the fact that an efficiency of 100 per cent in the operation of trucks is almost never obtained. If, for example, only eight trucks were available for this work, there would be a period of at least 48 days during which it would be impossible to provide both a stand-by truck against emergencies and the extra hauling truck which practical experience has demonstrated is necessary if the innumerable small delays and occasional breakdowns encountered in truck operation are not to affect the output of the mixer. If the ninth truck is purchased, the period when there will be neither an extra truck in the train nor a stand-by truck will be reduced to 24 days. Just what insurance a contractor should have against truck delays will depend somewhat on what he can afford. The ninth truck will carry itself, so the insurance it gives him against day-to-day losses of one sort and another really costs him nothing. Therefore it certainly ought to be procured. The tenth does not carry itself and has reduced insurance value. To own it is not as certainly profitable. But as with other forms of insurance, its cost may serve to avoid more serious loss.

For a job of this character, it would, then seem to be desirable to provide the last two trucks, making 10 in all, and, as a matter of operating policy, to make definite plans to insure that when the long haul is reached every available truck will be in such perfect condition and the driving so carefully supervised that during the brief period when all of the transportation equipment is needed, the highest possible efficiency will be obtained. Every contractor will understand that on a job of this kind the period of long haul almost invariably follows a period of short haul during which any trucks needing the services of a mechanic can be attended to without delaying the material delivery.

#### Hired Trucks the Best Solution for Extra-Long Hauls

When the problem is analyzed in this manner it becomes apparent that this general rule applies, viz., that contractors should own as many trucks as may be needed to provide full delivery up to the longest haul commonly encountered, but that the last mile of this ordinary maximum haul can reasonably be undertaken without a surplus truck in the train and without stand-by equipment in the yard.

On the other hand, there is the occasional job where the maximum haul will considerably exceed the maximum of the average job. To buy a full truck equipment for a job of this sort might, in theory at least, leave the contractor with a number of trucks on which, in ordinary years, he could not reasonably expect to earn even the stand-by cost. In a case of this kind, though special conditions may suggest a

different treatment, the contractor's safest policy ordinarily lies in furnishing a standard truck equipment and renting the additional trucks needed for the extra-long hauls. While it is, of course, advisable that the hired trucks be uniform in general characteristics with those regularly used on the job, this is not necessary. Such trucks should be hired when needed and laid off as fast as the haul distance shortens. If they are hired only to meet the long-haul conditions and that fact is fully understood by the owner, the scheme can be made to work very well. Trucks for this purpose will generally cost a little more than trucks hired for the whole job, but ordinarily this is more than offset by savings in mixer time.

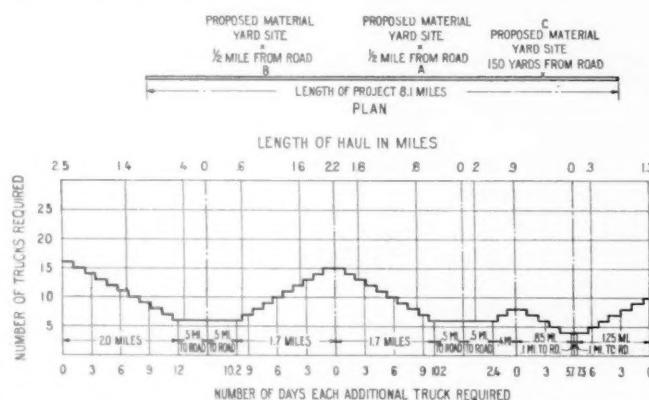


FIG. 5.—Relation of location of material yard to truck supply required (see figs. 3 and 4). If the contractor had hauled from the three sites shown, the cost of hauling would have been reduced to the lowest possible level

Take an example. The conditions on a certain job are such that the mixer must start 6 miles from the batcher plant. With a full truck supply this mixer has been producing 40 batches an hour. The contractor having found that 4 miles is his customary maximum haul has available only 15 heavy-duty two-batch trucks. But 22 such trucks are needed to deliver 40 batches an hour to the mixer against the 6-mile haul. What can he afford to pay for the 7 extra two-batch trucks or the 11 single-batch trucks that he will require to maintain his customary rate of production?

In the first place, if 22 trucks are required to produce 40 batches, 15 trucks can produce only a little over 27 batches an hour. But 40 batches per hour is an 83.3 per cent utilization of the working day, whereas 27 loads represent only a 56.2 per cent utilization. A full truck supply will, therefore, mean a saving of 27 per cent of the working day (which in this series of articles is assumed to be 10 hours long) or 162 minutes—worth, on the basis previously deduced, approximately \$80. The contractor has enough trucks to maintain his customary production up to a 4-mile haul. There are, therefore, 2 miles over which losses in mixer time due to inadequate truck supply will, if no trucks are added, range from zero at 4 miles to \$80 a day at 6 miles, an average of \$40 per day. It has previously been shown that, at 40 batches per day, laying a mile of ordinary concrete road takes about 6 days, but laying at the rate of 27 batches will require about 9 days. The time required, without additional trucks, to lay the 2 miles furthest removed from the batcher plant will, then, be about 15 days. Having an adequate truck supply for this work should, therefore, be worth about \$600. Now, as the cost of hauling is not affected by the number of units used in performing the haul, and if the contractor can employ extra trucks at a rate no

higher than the cost of his own trucks, he can save all of this \$600. If he has to pay a higher rate than he allows himself for his own trucks, the difference merely reduces the saving possible from operation on a basis of normal production. If the difference is greater than the possible saving—in this case \$600—renting trucks for this purpose would be unprofitable.

#### THE KIND OF TRUCKS

Another question that presents itself is, what sort of trucks should contractors provide for this work? No effort will be made to answer this question in detail at this time but certain phases of the matter are apparent.

1. The capital outlay involved in equipping with single-batch trucks is low. On the basis of a 5-mile maximum haul and the assumptions that have been made with respect to the relative speed of the several classes of trucks, 29 single-batch trucks are needed as against 12 high-speed, two-batch trucks. The 29 single-batch trucks would cost in the neighborhood of \$20,000 as against a somewhat variable maximum (depending on the make of two-batch trucks used) of perhaps \$60,000.

2. The weight of a five-bag batch (sand, coarse aggregate, and cement) varies because governing specification requirements vary a good deal, but will, at times, exceed 3,500 pounds. This is too great a load for most of the single-batch trucks now in use and as a result their rate of depreciation is high. Two-batch trucks are relatively stronger and the rate of their depreciation is not visibly affected if reasonable care is exercised in their use on this work. With due allowance for an occasional factory overhauling, their depreciation should not exceed \$700 to \$800 a year. Single-batch trucks are commonly turned over to inferior drivers and are poorly cared for. In practice when due allowance is made for time spent in the repair shop, two and one-half single-batch trucks of the type most commonly used may be considered the equivalent of one high-speed truck. A depreciation rate of \$300 per year on these trucks is, therefore, about equivalent to the rate given above for high-speed, two-batch trucks.

3. The cost of current repairs and lost time while repairs are being made appears to be a larger factor where single-batch trucks are used than where two-batch trucks are used.

4. On a job where the haul runs from practically nothing to 5 miles—to use a single illustration—the pay roll should carry an average of 16 drivers at an average rate of about \$3.50 a day or \$56 if single-batch trucks are used. As against this the pay roll would carry an average of eight drivers at perhaps \$4 or \$32 a day for high-speed, two-batch trucks. During a season of 150 working days this difference generates a pay roll saving in favor of the high-speed two-batch trucks which amounts to about \$3,600. Savings in gas and oil will increase this amount to well over \$5,000. This is some 12 to 15 per cent of the difference in cost ordinarily involved.

#### CONTRACT HAULING NOT AN UNQUALIFIED SUCCESS

Within the past few years quite a number of companies have come into existence which make hauling their business. Some of these specialize on highway construction work and within the past few years they have become a considerable factor in the concrete paving business. The theory on which they work is

that as all highway work, and particularly concrete paving, is seasonal, and as the haul distances on a normal project are variable, trucks operated by a contractor must earn fixed charges during a relatively short average season. The motor truck company, on the other hand, has greater opportunity for the continuous employment of its trucks and a relatively long season over which to distribute the fixed charges.

Reverting to the case previously used as an illustration (a 16-mile project handled by two-batch high-speed trucks from two loading points), it is apparent that of the 10 trucks desirable for this work, three would be used 96 days each, one 84 days, one 72 days, and one would be used 60, 48, 36, 24, and 12 days, respectively, a total of 624 days. This amounts to an average of 62 days or, in practice, to an average of somewhat more than three calendar months of actual operation, and this is a fair year's work. To make the ownership of these trucks profitable they must, of course, cover the year's fixed charges during this relatively short working period, beside depreciation, operating expenses, repairs, etc., while working and show a profit. It is by no means true that paving contractors commonly handle more than this amount of work during a working season; that they consistently obtain other work for their trucks when they are not employed on paving work; or that the work in the hands of even the larger paving contractors is so located that an interjob transfer of even so mobile a piece of equipment as a truck, is or can be made to meet changing length of haul. The owner of a large number of trucks has, therefore, a strong argument in his favor when he offers to relieve the main contractor of the financial burden which a full equipment of trucks imposes on him. The practice of renting trucks has, therefore, grown in popularity.

Where this plan has been found in operation on going projects it has not, however, been an unqualified success. On one of the projects observed the main contractor, firmly entrenched behind a contract guaranteeing the delivery of material to him at a fixed cost per square yard of pavement laid, was thereafter indifferent as to the location of his material yard with the result that the haul was needlessly lengthened to the material detriment of the subcontractor. On another job, the main contractor installed a loading plant which operated so badly that the trucks could not make a reasonable number of trips per day and lost money from this cause. This trouble was complicated by a long delay, amounting to three weeks or more, in moving from the first set-up to a second set-up. During this period the trucks which had been working on the job were withdrawn and when the main contractor was ready to begin operations again there was a good deal of trouble in getting a new truck train. On another job the subcontractor provided trucks which were originally believed to be sufficient to meet the haul requirements but when the main contractor improved the efficiency of his operation, the subcontractor was unable or unwilling to supply additional trucks.

Other illustrations could be given but these should make the point reasonably clear, namely that, as the profit on a paving operation is so largely dependent on adequate and dependable material delivery, and the profit on the operation of the trucks is so dependent on efficiency at the loading plant and the mixer, these operations should never be allowed to come wholly into the hands of different men, for their apparent interests are bound to clash at times with the result that the

profits of both suffer. This is, of course, quite a different situation than that which arises when a contractor employs a few trucks for a few days in order to maintain production against an unusually long haul. Here the amount at stake generally is not great and the employment of a few trucks to meet a special condition in no way places the contractor at the mercy of a subcontractor whose interests may at times seem to clash with his own.

#### SUBGRADES LIMIT USE OF HEAVY-DUTY TRUCKS

Large heavy-duty trucks offer a means of somewhat reducing the investment in trucks. A 5-ton truck will readily carry three batches and with only a moderate overload will carry four batches. A 7-ton truck will carry four batches and with moderate overload will carry five. These trucks can be reasonably depended on to average 12 miles an hour and, where loading facilities are reasonably well designed, the formulas for trip time will be as follows:

For three-batch trucks,  $T=10d+9$ . For four-batch trucks,  $T=10d+11$ . For five-batch trucks,  $T=10d+14$ .

If the cement is hauled in separate trucks, and a multiple-batch device is used for loading the aggregate, these formulas reduce to:

For three-batch trucks,  $T=10d+6$ . For four-batch trucks,  $T=10d+7.5$ . For five-batch trucks,  $T=10d+9$ .

If delivery capacity were the only consideration the large, heavy-duty truck would be widely used, as it is a dependable piece of equipment and the investment required in order to insure an adequate supply of material at the mixer against hauls of ordinary length is relatively low. It is not widely used, however, nor is it likely to be, because of its effect upon the subgrade. It takes a good while for even the best subgrade to dry out enough in the spring to carry these large trucks without serious rutting, and subgrades composed of the more plastic materials, such as heavy clays, gumbo, etc., often do not become stable enough to permit profitable operation until late in the fall. The season during which they can work without creating subgrade conditions both difficult and expensive to correct is, therefore, short. There is also to be considered the fact that whenever the subgrade is badly distorted the best attention probably does not leave it in a thoroughly satisfactory condition; and that the corrective measures tend to interfere with high production. Finally any rutting of consequence displaces so much material that the forms are thrown out of grade and alignment with the result that the contractor finds himself under a more or less constant extra expense in dealing with both the subgrade and the forms and the State or municipal organization responsible for the quality of the work, finds itself constantly in some doubt as to whether the best treatment that the contractor can give to the damaged subgrade really returns it to proper condition. The accumulation of these difficulties develops a cost, tangible in so far as it involves extra personnel, more or less intangible in so far as it adversely affects production, which measurably offsets the low delivery cost that these units show when operating over stable roads.

#### INDUSTRIAL RAILWAY HAULAGE

The opposite condition prevails where industrial railway is used. The general practice is to run the

industrial railway on the shoulder, a practice which permits of the uninterrupted preparation of subgrade and setting of forms without danger that either will be damaged by any operation incident to the delivery of materials at the mixer. This is the greatest merit of the industrial railway system of material delivery. It is an element deserving of serious thought, for under the conditions prevailing during the spring and after any protracted rain, the subgrade is apt to be so soft that trucks of any kind distort the finished work to some extent, making it practically impossible to obtain the accuracy in the final finish of the subgrade which is theoretically desirable. Even during the drier months, from June to October, the practices which must be followed in the fine finishing of the subgrade preparatory to placing concrete, result in some irregularity and, as the operation of trucks over this finished work tends to accentuate any such irregularity, it is not practical to insist on the refinement which can be beneficially obtained when the industrial railway is used.

In spite of the advantage which the industrial railway has in this particular, its use appears to be decreasing. There are a number of reasons for this. Perhaps the most influential is the fact that, as the industrial railway is not generally used on any highway construction work except concrete paving, a contractor who invests in this form of equipment finds that a large part of his working capital is tied up in equipment serviceable only when concrete paving work can be had. Another aspect is the high cost involved. Twenty-pound track with ties, switches, etc., is worth perhaps \$5,000 a mile. Engines cost from \$3,000 to \$6,000 each. Cars are worth about \$85 each and batch boxes about \$60. Necessarily these figures are general but they give some idea of the delivered cost of this equipment to the contractor. In fairly level country from 24 to 30 batches can be hauled per train and if the trains are operated at 6 miles an hour—a rather common speed—the train cycle is somewhat as follows:

	Minutes
Loading train	20 to 30
Running time (5 miles)	90 to 100
Switching at mixer	10 to 15
Unloading at mixer	35 to 45
<hr/>	
Time per round trip	155 to 190

If the project is fairly level and production in the neighborhood of 40 batches an hour is to be obtained, it is, therefore, necessary to provide at least 4 engines, 60 cars, and 120 batch boxes, besides 5 miles of track with switches, etc. If, on the other hand, the country is hilly, the length of the trains must be cut down or helper engines put into service. Against grades of 5 or 6 per cent, which are common in highway work, a good engine will handle only 4 to 6 cars—8 to 12 batches—over track such as is commonly found on paving jobs. Where such grades will be encountered two or three extra engines must, therefore, be supplied. It is not necessary to go into the matter in greater detail to make it clear that the cost of full industrial railway equipment for a 5-mile maximum haul may, readily reach \$75,000. To obtain a reasonably accurate view of the comparative investment in transportation equipment which is involved, this sum should be compared with the \$20,000 required for single-batch trucks and the \$60,000 required for high-speed two-batch trucks to meet the same maximum haul.

Direct delivery costs, however, are low even in rolling country. An engineer and a helper will handle a train which, in level country, may carry as much as 30 batches. Assuming that three-and-a-half trips a day are possible, this would constitute a delivery of 105 batches per crew per day. Such a crew (engine driver and helper) would cost not more than \$10 per day, so it is clear that the direct labor cost involved is very low. Even when hills are encountered the labor cost would seldom be more than doubled. On short hauls the showing is not quite so favorable since the time required to load and unload the train is not affected by the length of haul. For level country, however, the average direct labor cost of delivery by industrial railway up to a 5-mile haul may drop below 8 cents a batch and even with some heavy grades may be as low as 15 cents a batch.

The actual cost of delivery, as affecting the contractor's profit and as determining what type of hauling equipment to purchase is, however, quite another matter. In its last analysis, no matter what sort of equipment is used, the cost of delivery must include all such items as: Getting equipment onto the job; special services and facilities; interest and depreciation; operating cost (labor and materials); transfer from one set-up to another on the job; and return to winter storage. These, of course, generate direct and tangible costs. But there are also certain intangible costs. If the hauling equipment breaks down there is a loss of earnings on the equipment and a cost of repairs. But there may also be a loss of output at the mixer. Commonly the crew working at the mixer and on correlated operations is of practically constant size. The pay roll is, therefore, constant. If, then, batches are dropped because the hauling equipment breaks down there is an indirect loss which may, and often does, exceed the direct losses charged against the equipment itself. No study of the relation which one style of transportation equipment bears to another is even measurably complete until it covers both of these fields, and conclusions drawn on any narrower basis are bound to lead to costly errors.

#### REASONS FOR DECLINING USE OF INDUSTRIAL RAILWAYS

Returning, then, to the cost of transportation by industrial railway and subjecting it to further analysis, it will be apparent that moving an industrial railway from job to job is expensive. Track, ties, switches, locomotives, cars, batch boxes, etc., to cover a 5-mile haul weigh at least 350 to 400 tons. To place any general estimate on the cost involved in moving such a weight of equipment is impossible, for the conditions governing differ too widely. However, as a common condition, getting this equipment onto the job would involve loading it onto trucks, hauling it to a railroad station, loading it onto cars, shipping it to the site of the new work, unloading it onto trucks, hauling it to the road and distributing it along the road. All of these operations cost a good deal.

Special facilities include repair shops, fuel-supply equipment, etc. Installations of this sort must be of about the same nature as on a truck job, although there is, in general, less work for the expert mechanic and more on cars, batch boxes, etc., for the blacksmith.

Interest on working capital needs no special discussion. Depreciation of equipment is rather high. Locomotives generally are of the gasoline engine type. They are well built, but suffer from wear and tear to about the same degree as heavy trucks of the same

grade of construction. Track is given rough, even abusive, treatment, as are cars, batch boxes, etc. These do not wear out rapidly but careless handling and the common preference for the sky as a roof over them in all sorts of weather renders them unfit for valuable service long before they ought to go to the junk dealer. There is, therefore, no apparent reason for assuming lower rates of depreciation on industrial railway equipment than are considered applicable to other forms of heavy equipment.

The direct labor element in operating cost has been discussed. It is low. The fuel, and correlated costs, are equally low. But, in addition to the direct labor used in the operation of trains, track laying and track maintenance must be included under operating cost. The labor requirements under this heading are variable. In good weather three or four trackmen are all that are commonly used. In wet weather as many more may be needed to keep the track in passable condition. If the job is so long that the track can be used more than once, it must be taken up and relaid. The common practice is to begin operations at the point nearest the material piles, working away from them to the end of the project, laying track about as fast as the progress of the mixer requires. When the end of the first leg is reached the mixer returns to the point at which work began and works out in the opposite direction. This releases the track to be torn up and relaid as the mixer progresses.

Generally the track is torn up from the far end and hauled back by a work train. But whether this system is used or trucks or wagons are employed, it is an expensive operation. A gang of from four to six men is required to tear up and load the track and a train of cars or trucks is required to haul it, in addition to the gang used in relaying it. Finally, when the job is finished, all of the track and equipment must be accumulated and piled, and locomotives housed, pending shipment to warehouses or to the next job. All of these operations are expensive, as track is heavy and cumbersome. No very definite idea of their cost can be given in an article such as this for they are subject to so many variations from job to job that even illustrative examples are likely to prove deceptive. They have been mentioned only because no contractor can obtain even an approximate view of industrial railway hauling costs until he has given these matters consideration in the light of such experience as he may have had with this or other types of equipment.

The above deal with tangible direct costs. Besides these, the bureau's studies indicate that there are definite indirect costs to be dealt with. Thus, for instance, it is hard to get full production from the mixer when industrial railway is used. Tables 6 and 7 show readings which bring this out. The time taken in shifting trains is a common cause of mixer delays. Derailments are also a common cause; these not only cause rather frequent mixer delays, but also the spilling and loss of numerous batches. On one job which the writer visited this year a train had gone into the ditch an hour before he arrived, a second had been derailed and most of the batches spilled two or three days before, and in a third location there was evidence that another wreck had recently been cleared away. Between 30 and 40 cars were involved in these wrecks, and although exact figures as to the losses which had been involved were not available, the foreman stated that between 30 and 40 batches had been lost. These were 5-bag batches, and the cement involved alone amounted to quite a tidy sum.

TABLE 6.—*Operation time losses on industrial railway job*

Date (1925)	Proportion of working time mixer was in operation	Percentage of working time lost due to various causes					
		Waiting for train	Train derailed	Slow operation of mixer	Waiting for materials at railroad	Miscellaneous	
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Mar. 19.	28.0	45.4	26.1	0.7	29.2	1.0	
Mar. 20.	34.9	35.0			48.2		
Mar. 21.	51.9						
Mar. 22.	50.8	48.5		.7			
Mar. 23.	44.6			.2	42.3	13.1	
Mar. 24.	54.4	28.4				18.0	
Mar. 25.	52.0	44.7		1.4		2.4	
Mar. 26.	63.4	25.6		10.7			
Mar. 27.	66.1	16.7				17.3	
Mar. 28.	62.6	13.4				23.9	
Mar. 29.	44.4	54.2		1.4			
Mar. 30.	30.5	69.1		.6			
Mar. 31.	42.2	56.3		.5		1.3	
Mar. 19.	80.5	12.4				7.1	
Mar. 19.	58.5	40.0		.2		1.2	
Average	51.0	32.6	1.7	1.1	8.0	5.7	

TABLE 7.—*Operation time losses on industrial railway job*

Date, 1925	Proportion of working time mixer was in operation	Percentage of working time lost because of various causes													
		Handling batch boxes		Spotting cars		Switching		Mixer trouble		Slow operation of mixer		Moving mixer	Water supply	Fuel supply	Miscellaneous
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
Sept. 26.	44.7	1.7	5.5		3.0	3.8	5.1			36.2					
Sept. 28.	46.5	5.3			37.3		10.9								
Sept. 29.	67.6	10.9				9.7				11.8					
Sept. 29.	61.7	9.7				5.9				10.7		6.2			
Sept. 30.	43.3	6.1	1.0							4.0	20.6		25.0		
Sept. 30.	63.0	11.3	7.3							6.9	5.7		2.5	3.3	
Oct. 1.	69.2	3.2	3.1	17.9	1.9					.9		3.8			
Oct. 2.	45.2	16.0	9.6							9.9	1.7		2.2	15.4	
Oct. 3.	41.1	1.1	18.0							4.6				35.2	
Oct. 9.	55.1	6.5	2.8	8.4						6.7	20.5				
Oct. 9.	49.0	2.0			10.0	1.9	5.6	31.5							
Oct. 10.	35.1	.9	4.8		54.1	.5	2.2	2.4							
Oct. 12.	39.0	5.1			11.2					5.2	5.4		34.1		
Oct. 12.	55.2	10.0			22.7					7.5	2.5		2.1		
Oct. 13.	53.0	5.6			22.5	12.5	2.2	2.4					1.8		
Oct. 14.	49.4	6.6			17.9		.6	1.2	22.3				2.0		
Oct. 15.	60.3	11.0			13.8	5.1				9.8					
Oct. 15.	40.9	1.4			10.0	1.2	20.2	26.3							
Oct. 16.	65.6	3.2			7.8		2.7	20.7							
Oct. 16.	40.4	4.0			2.0	39.7	1.1	2.8	10.0						
Oct. 16.	77.0	2.6			.9	12.2	5.5						1.8		
Average	52.5	6.0	2.5	12.0	4.2	4.1	9.1	1.5	2.1		6.0				

NOTE.—No time losses because of rain or similar causes are included in this study.

#### HEAVY LOSSES CAUSED BY POOR TRACK LAYING

Losses of this character arise from the fact that the track is seldom given proper attention. In the first place the shoulder on which it is laid is apt to be composed of loose dirt. Such effort as is made to obtain a smooth bed on which to lay the track is likely to be confined to running a blade grader over the shoulder which, though it may leave a fairly smooth bed for the track, creates this condition by cutting off the high spots and filling the low spots. As not much is done to consolidate the loose material left in the low spots, the track initially rests on a nonuniform grade. Generally the track is then laid without much attention to exact alignment or to producing a uniform gradient. As the trains run over the track such irregularities as are permitted when it is laid are accentuated with the result that even in good weather trains have to proceed cautiously. As much of the subgrade on which the

track rests is soft, it absorbs water freely during rains. Water also gets into the depressions under the ties.

It may be observed that at least some of these common conditions are avoidable. The loss of time from switching trains at the mixer is not, for instance, a necessity. It arises from the fact that switching is commonly done between the mixer and the loading bins. This, of course, requires that the empty train be pulled out before a loaded train can be run in. If the track laying is kept well in advance of the concreting and the switching is done ahead of the mixer, an adequate supply of loaded cars can be maintained at the mixer while this switching is being done. That this is not a more common practice is probably owing to the fact that the fine finishing requires more or less movement of material to and from the shoulders, and that, therefore, it is not advisable to attempt to lay track until this operation has been completed. Where switching ahead is practiced, the supply of forms must, therefore, be large and the final subgrading must be carried on much farther in advance of the mixer than is done on jobs where other forms of material delivery equipment are used.

Neither are the frequent derailments and the loss of materials necessary conditions. Track can be laid on good alignment and at a true gradient with little if any greater cost than is involved in present practices. This merely requires that the foreman in charge of track laying shall know how to lay track properly, and that he use this knowledge. The shoulder should be rolled to eliminate soft spots quite as carefully as the subgrade is commonly rolled and where the ground is likely to remain soft, ballast should be added. Finally, the track should be under constant maintenance. These operations will, it is true, increase the tangible operating cost but they will decrease the intangible cost arising from derailments and from delays in the delivery of material to the mixer, costs which are likely materially to exceed the direct cost of keeping a few men at work on track maintenance.

Delivery by wagon to the job, where materials were piled along the subgrade and later moved to the mixer in wheelbarrows, was at one time the standard practice. It has now been all but abandoned. The fact that more or less material was lost was a factor, but the great objection to this method lay in the poor proportioning which resulted from using wheelbarrows as measuring boxes.

#### LOCATION OF LOADING PLANT IMPORTANT

From the above discussion it will be apparent that in any effort to develop a high rate of production the handling of materials is an important consideration. It must also be apparent that the cost of hauling is a large element in the total cost of paving work. Indeed, it is so high that the location of material piles becomes a matter of primary consideration if profitable operation is to be insured. Just how essential the proper location of the material loading plant is has been shown graphically in Figures 3, 4, and 5. It may be further developed by a mathematical study of the effect of distance on the hauling cost. Thus, by reference to Table 5 and to formula No. 2, it will be seen that on a basis of full operating efficiency something over 30 single-truck days are required for the delivery of the materials for an average mile of ordinary 18-foot pavement. If to this is added the extra truck or two needed to insure against delays, the truck time involved will be seen to average about 35 days per mile of pave-

ment per mile hauled. A fair allowance for single-batch trucks (driver, oil, gas, and tires, repairs, depreciation, profit, etc.) is from \$9 to \$10 a day, which results in a hauling cost of from \$315 to \$350 per mile. Necessarily these figures are approximate, for various factors will affect both the number of truck days and the actual average cost of operating a truck, but they are reasonably accurate for the conditions assumed and sufficiently so to illustrate the point involved, namely, that cost mounts rapidly with the distance materials must be moved. With this as a basis, it will be obvious that haul develops cost about as follows:

Miles of pavement	Cost of hauling for each mile	Total cost of hauling to end of each mile	Miles of pavement	Cost of hauling for each mile	Total cost of hauling to end of each mile
First.....	\$350	\$350	Fifth.....	\$1,750	\$5,250
Second.....	700	1,050	Sixth.....	2,100	7,350
Third.....	1,050	2,100	Seventh.....	2,450	9,800
Fourth.....	1,400	3,500	Eighth.....	2,800	12,600

The above development is for single-batch trucks. A table for any other style of truck would show the same characteristics. With industrial railway, because train operation is so small a factor in total operating cost, a development of this sort does not apply. Cost, with this form of transportation, is more nearly uniform.

Where a job layout is under consideration the cost of haul must be equated against the cost of moving the material handling plant. Take a typical case as shown in Figures 3, 4, and 5, which is from a project that roughly parallels a railroad and is 8.1 miles long. Station A is 3.4 miles from the south end of the road and half a mile off the road. Station B is 6.1 miles from the south end of the road and also one-half mile off the road. Station C is 1 1/4 miles from the south end of the road and only 150 yards from the road. All existing roads are unimproved. Should the contractor (1) make one set-up at A, (2) a set-up at B and one at C, or (3) a set-up at A, one at B, and one at C. The set-up at A would involve a 5.2-mile haul north and a 3.9-mile haul south from the set-up which by reference to the above figures will be seen to involve hauling costs as follows:

South from A, 3.9 miles.....	\$3,360
North from A, 5.2 miles.....	5,670
Total.....	9,030

The layout involving set-ups at B and C will involve hauling costs as follows:

South from B, 2.7 miles.....	\$1,785
North from B, 2.5 miles.....	1,575
South from C, 1.3 miles.....	560
North from C, 2.7 miles.....	1,785
Total.....	5,705

This arrangement of the haul is preferable to the first if the move from B to C can be made for less than \$4,325. The layout involving set-ups at A, B, and C will involve hauling as follows:

South from B, 2.2 miles.....	\$1,260
North from B, 2.5 miles.....	1,575
South from A, 0.9 miles.....	315
North from A, 2.2 miles.....	1,260
South from C, 1.3 miles.....	560
North from C, 0.9 miles.....	315
Total.....	5,285

The third arrangement is preferable to the second if the third set-up can be made for less than \$420 which

is not likely. Contractors face such problems as this on almost every job undertaken and more often than might be supposed a failure to properly analyze the situation results in dropping profits that, with a little careful thought, could easily have been saved.

Besides the difference in haul and hauling cost that different arrangements of the loading points yield, these different plans present very different maximum hauling equipment requirements. This also is an important matter. To insure full delivery of material to the mixer under the first plan more than 30 trucks would be needed. Under the second plan the maximum haul is only 2.7 miles and 18 trucks would meet all requirements. Moreover under this plan the average utilization of the trucks would be relatively high because there are four points of maximum haul—three of about the same length, as compared with two in the first case. It is not necessary to extend this discussion to justify the statement that the cost of haul increases so rapidly as the length of haul increases, and the number of trucks required for high production is so affected by long haul, that careful consideration should be given to this point, not only by contractors but also by those responsible for planning and locating highway work of this character.

(Continued from page 219)

In West Virginia and Kentucky corporate ownership has apparently not developed to the stage reached by Maryland and Connecticut. In each of these States the individuals and partnerships operate 64 per cent of the busses. This condition is reversed again, however, in Washington, which is more similar to the first two States, the corporations, which are only 30 per cent of the number of operators, controlling 55 per cent of the busses. The individual operators in this State own an average of 2.2 motor busses, the partnerships 3.1, and the corporations an average of 6.9.

The tendency toward consolidation has proceeded further in Maryland than in the other States, and the data available for the two years, 1924 and 1925, indicate the rapidity of the development. The 106 busses in 1924 were operated by 43 owners; by 1925 the number of busses had increased to 161 with the addition of only one to the number of operators. Eight operators owned approximately 50 per cent of the busses in 1924, and by 1925 the same percentage was in the hands of only three operators. However, there were just as many small operators in the latter year, and the increase in the number of busses reflected the greater number of busses owned by a few operators. The change came about largely as the result of the expansion of the business of one company, which in 1924 owned only 13 busses and by 1925 had increased the number of its vehicles to 57. This company has operated this year over 15 distinct and separate routes, varying in length from 12 to 71 miles.

The studies that have been made indicate clearly that the motor vehicle is rapidly becoming an important agency in the common-carrier service of the public, involving, of course, an increase in the importance of the highways which serve as the avenues for this new type of public service. The studies inspire a feeling of confidence that the motor bus, as well as the motor truck, is capable of becoming an invaluable ally of the rail carriers by making it possible to reach sections of the country not supplied with railroad facilities and by facilitating the movement of passengers over short distances where rail service is to a certain extent slow and inconvenient.

## ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS

*Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets or to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.*

### ANNUAL REPORT

Report of the Chief of the Bureau of Public Roads, 1924.  
Report of the Chief of the Bureau of Public Roads, 1925.

### DEPARTMENT BULLETINS

- No. 105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.  
\*136. Highway Bonds. 20c.  
220. Road Models.  
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.  
\*314. Methods for the Examination of Bituminous Road Materials. 10c.  
\*347. Methods for the Determination of the Physical Properties of Road-Building Rock. 10c.  
\*370. The Results of Physical Tests of Road-Building Rock. 15c.  
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.  
387. Public Road Mileage and Revenues in the Southern States, 1914.  
388. Public Road Mileage and Revenues in the New England States, 1914.  
390. Public Road Mileage and Revenues in the United States, 1914. A Summary.  
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.  
\*463. Earth, Sand-Clay, and Gravel Roads. 15c.  
\*532. The Expansion and Contraction of Concrete and Concrete Roads. 10c.  
\*537. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests. 5c.  
\*583. Reports on Experimental Convict Road Camp, Fulton County, Ga. 25c.  
\*660. Highway Cost Keeping. 10c.  
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.  
\*691. Typical Specifications for Bituminous Road Materials. 10c.  
\*704. Typical Specifications for Nonbituminous Road Materials. 5c.  
\*724. Drainage Methods and Foundations for County Roads. 20c.  
\*1077. Portland Cement Concrete Roads. 15c.  
\*1132. The Results of Physical Tests of Road-Building Rock from 1916 to 1921, Inclusive. 10c.  
1216. Tentative Standard Methods of Sampling and Testing Highway Materials, adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal-aid road construction.

- No. 1259. Standard Specifications for Steel Highway Bridges adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal-aid road work.  
1279. Rural Highway Mileage, Income and Expenditures, 1921 and 1922.

### DEPARTMENT CIRCULAR

- No. 94. TNT as a Blasting Explosive.  
331. Standard Specifications for Corrugated Metal Pipe Culverts.

### FARMERS' BULLETINS

- No. \*338. Macadam Roads. 5c.  
\*505. Benefits of Improved Roads. 5c.

### SEPARATE REPRINTS FROM THE YEARBOOK

- No. \*727. Design of Public Roads. 5c.  
\*739. Federal Aid to Highways, 1917. 5c.  
\*849. Roads. 5c.

### OFFICE OF PUBLIC ROADS BULLETIN

- No. \*45. Data for Use in Designing Culverts and Short-span Bridges. (1913.) 15c.

### OFFICE OF THE SECRETARY CIRCULARS

- No. 49. Motor Vehicle Registrations and Revenues, 1914.  
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.  
63. State Highway Mileage and Expenditures to January 1, 1916.  
\*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.  
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.  
161. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Highway Act and Amendments Thereto.

### REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH

- Vol. 5, No. 17, D-2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.  
Vol. 5, No. 20, D-4. Apparatus for Measuring the Wear of Concrete Roads.  
Vol. 5, No. 24, D-6. A New Penetration Needle for Use in Testing Bituminous Materials.  
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.  
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.

\* Department supply exhausted.

## UNITED STATES DEPARTMENT OF AGRICULTURE

## BUREAU OF PUBLIC ROADS

## STATUS OF FEDERAL AID HIGHWAY CONSTRUCTION

AS OF

NOVEMBER 30, 1925

STATES	FISCAL YEARS 1917-1925			PROJECTS COMPLETED SINCE JUNE 30, 1915			PROJECTS UNDER CONSTRUCTION			PROJECTS APPROVED FOR CONSTRUCTION			BALANCE OF FEDERAL AID FUND AVAILABLE FOR NEW PROJECTS		STATES		
	PROJECTS COMPLETED PRIOR TO JULY 1, 1925			TOTAL COST FEDERAL AID MILES			ESTIMATED COST FEDERAL AID ALLOTTED MILES			ESTIMATED COST FEDERAL AID ALLOTTED MILES			MILES				
	TOTAL COST	FEDERAL AID	MILES	TOTAL COST	FEDERAL AID	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES		
Alabama.....	\$ 5,970,097.71	\$ 2,863,197.66	611.8	\$ 6,001,064.21	\$ 2,842,164.67	341.4	\$ 9,558,740.58	\$ 4,684,244.44	488.0	\$ 953,521.33	\$ 431,336.34	26.7	\$ 2,007,112.69	\$ 1,003,558.00	Alabama		
Arizona.....	3,160,133.43	1,016,119.34	1,161.8	1,360,119.34	1,007,860.13	101.7	1,160,133.41	1,241,016.21	151.3	1,160,133.41	1,160,133.41	10.0	1,988,169.37	1,360,119.34	Arizona		
Arkansas.....	13,216,130.68	5,658,260.41	1049.9	2,182,260.41	1,182,260.41	101.4	6,809,860.60	3,173,371.80	452.8	430,437.49	212,839.99	31.2	1,380,831.32	1,380,831.32	Arkansas		
California.....	22,346,175.39	11,719,814.34	864.8	2,036,163.76	483,584.79	35.8	11,660,170.47	5,686,170.36	354.2	108,448.05	61,331.34	1.8	2,297,076.22	2,297,076.22	California		
Colorado.....	11,876,703.94	6,067,814.34	661.7	867,420.69	1,011.6	1,011.6	4,153,748.94	2,288,899.89	239.9	108,339.63	61,331.34	7.1	2,097,167.65	2,097,167.65	Colorado		
Connecticut.....	4,568,639.80	2,989,368.66	1,011.6	465,744.13	212,549.45	12.3	980,042.66	4,370,744.76	227.7	15,815.91	7,907.95	0.1	10,912.65	10,912.65	Connecticut		
Delaware.....	4,281,559.81	1,496,407.97	966.3	2,241,919.38	1,084,752.54	131.6	1,141,723.61	5,380,408.07	281.8	650,337.04	274,351.79	41.5	761,040.66	761,040.66	Delaware		
Florida.....	2,982,273.72	9,406,366.46	1,748.9	600.01	211,619.32	121,988.48	24.5	3,184,329.61	1,997,516.39	206.0	603,213.91	359,940.73	16.1	324,885.09	324,885.09	Florida	
Georgia.....	80,156,028.37	9,406,366.46	1,748.9	1,816,332.66	1,816,332.66	1,816,332.66	1,844,149.69	4,044,261.40	890.9	543,675.62	346,553.10	346,553.10	346,553.10	346,553.10	Georgia		
Idaho.....	40,10,481.10	1,640,870.33	1,640,870.33	402.1	1,132,976.87	544,542.84	41.2	17,995,239.73	8,445,352.09	492.9	514,403.90	1,937,162.46	16.6	446,777.87	446,777.87	Idaho	
Illinois.....	13,638,172.65	6,562,455.68	442.1	1,722,462.52	320,266.06	26.6	10,748,366.11	3,486,669.59	499.7	1,074,988.46	514,403.90	125.5	1,937,162.46	1,937,162.46	Illinois		
Iowa.....	27,272,265.81	11,107,482.99	886.3	3,168,308.25	1,368,657.00	178.3	10,429,367.14	4,429,367.14	749.7	3,080,195.20	680,874.84	171.8	1,130,484.12	1,130,484.12	Iowa		
Kansas.....	26,399,695.77	9,755,273.32	881.4	6,205,894.69	5,566,94.9	66.9	665,291.14	17,673,290.91	323.8	352,618.16	176,309.07	16.8	1,071,015.06	1,071,015.06	Kansas		
Kentucky.....	14,822,324.28	6,422,324.28	877.6	875,723.86	411,319.04	64.9	3,115,016.67	1,435,944.69	138.6	457,653.44	229,929.84	7.2	855,568.87	855,568.87	Kentucky		
Louisiana.....	11,593,484.87	5,278,870.66	927.6	281,870.66	281,870.66	281.4	123,802.05	9.8	2,814,486.82	66.2	188,780.65	84.3	803,904.36	803,904.36	Louisiana		
Maine.....	8,174,261.31	3,807,870.33	3,807,870.33	1,777.1	1,921.85	289.4	2,814,750.61	1,241,581.15	126.2	1,241,581.15	1,241,581.15	1.9	19,267.56	19,267.56	Maine		
Maryland.....	8,139,566.90	3,807,870.33	3,807,870.33	1,777.1	1,921.85	289.4	2,814,750.61	1,241,581.15	126.2	1,241,581.15	1,241,581.15	1.9	19,267.56	19,267.56	Maryland		
Massachusetts.....	14,047,656.22	5,467,661.28	300.6	5,467,661.28	5,467,661.28	5,467,661.28	2,711,111.11	20.4	6,104,858.26	1,693,752.87	80.4	323,228.34	105,000.00	56.2	1,584,145.94	1,584,145.94	Massachusetts
Michigan.....	16,244,000.80	12,739,542.04	3,969.3	3,969.3	3,969.3	3,969.3	1,728,316.31	5,400,353.73	151.8	3,919,916.00	2,923,200.57	26.0	2,676,629.05	2,676,629.05	Michigan		
Minnesota.....	30,415,686.88	12,739,542.04	3,969.3	3,969.3	3,969.3	3,969.3	3,339.2	7,734,534.96	564.8	522,061.23	26,920.50	30.4	66,076.73	66,076.73	Minnesota		
Mississippi.....	10,292,285.79	4,986,175.73	883.4	1,442,014.26	729,145.42	110.0	8,430,035.47	448.4	755.7	1,134,406.98	755.7	231,932.43	231,932.43	Mississippi			
Missouri.....	17,386,156.67	8,219,411.43	1,118.9	1,103,119.51	1,103,119.51	1,103,119.51	1,103,119.51	1,103,119.51	110.0	10,386,545.98	48,617,89	29.2	4,192,949.20	4,192,949.20	Missouri		
Montana.....	10,156,600.41	5,317,523.15	921.6	607,212.46	474,272.96	57.9	1,345,024.85	1,345,024.85	186.3	1,345,024.85	1,345,024.85	117.9	544,084.41	544,084.41	Montana		
Nebraska.....	9,366,374.36	4,169,523.90	150.6	1,440,748.00	696,938.98	917.0	10,537,597.65	10,661,096.07	1066.0	616,557.65	407,874.58	59.8	2,337,714.56	2,337,714.56	Nebraska		
Nevada.....	16,204,000.80	3,969.3	3,969.3	5,741,869.76	5,741,869.76	5,741,869.76	4,171,111.11	1,693,752.87	80.4	3,816,052.30	412.4	1,662,571.67	1,662,571.67	Nevada			
New Hampshire.....	11,961,387.44	5,920,673.39	219.1	1,266,628.18	1,266,628.18	1,266,628.18	9,439,218.78	3,485,755.71	75.6	3,485,755.71	129,453.38	6.6	50,972.43	50,972.43	New Hampshire		
New Jersey.....	8,717,989.18	8,717,989.18	8,717,989.18	2,836,710.69	2,836,710.69	2,836,710.69	2,046,089.17	1,300,477.77	10.0	1,300,477.77	1,300,477.77	1.6	150,212.36	150,212.36	New Jersey		
New Mexico.....	28,597,679.69	18,229,076.67	18,229,076.67	631.5	1,580,987.05	1,580,987.05	1,580,987.05	33,931,726.76	667.3	1,046.0	1,046.0	152.5	3,352,700.23	3,352,700.23	New Mexico		
North Carolina.....	21,014,450.41	8,144,454.88	1,171.6	604,834.80	604,834.80	604,834.80	4,443,488.06	1,071.7	1,071.7	1,071.7	1,071.7	1.6	1,385,748.63	1,385,748.63	North Carolina		
Ohio.....	10,899,263.62	5,060,263.62	357.3	968,561.19	828,821.81	72.6	1,060,881.85	4,812.4	4,812.4	4,812.4	4,812.4	1.6	1,385,748.63	1,385,748.63	Ohio		
Oklahoma.....	4,155,697.86	4,155,697.86	331.4	331.4	331.4	331.4	1,060,881.85	4,812.4	4,812.4	4,812.4	4,812.4	1.6	1,385,748.63	1,385,748.63	Oklahoma		
Pennsylvania.....	11,961,387.44	5,920,673.39	219.1	1,933,600.16	983,457.45	87.2	6,950,244.64	3,316,666.39	93.6	1,306,405.40	1,306,405.40	17.1	298,017.87	298,017.87	Pennsylvania		
Rhode Island.....	2,638,436.08	1,119,686.08	64.8	64.8	64.8	64.8	6,065,432.46	1,065,536.18	160.3	987,642.80	1,347,552.21	15.9	1,131,988.74	1,131,988.74	Rhode Island		
South Carolina.....	11,153,347.84	6,121,387.84	1,147.9	1,081,372.51	367,871.74	58.6	2,017,073.06	619,548.63	631.7	616,566.10	197,730.00	13.2	310,128.65	310,128.65	South Carolina		
South Dakota.....	12,091,434.67	5,365,979.00	1,147.9	1,740,210.48	646,560.60	281.6	2,565,188.53	1,046,686.88	328.6	1,046,686.88	1,046,686.88	34.5	4,763,339.40	4,763,339.40	South Dakota		
Tennessee.....	13,765,140.98	6,725,072.47	1,147.9	5,061,934.93	5,061,934.93	5,061,934.93	1,202.5	4,649,550.26	348.4	4,649,550.26	348.4	34.5	69,129.42	69,129.42	Tennessee		
Texas.....	54,120,910.83	21,072,034.94	9,072,034.94	8,072,034.94	8,072,034.94	8,072,034.94	4,671.1	81,285,580.96	9,377,402.32	1,212.0	4,631,401.47	2,111,613.40	243.3	573,124.37	573,124.37	Texas	
Utah.....	6,268,165.41	3,816,156.41	425.1	1,321,126.89	92.0	92.0	5,246,305.87	2,903,061.56	256.6	2,903,061.56	2,903,061.56	15.9	677,534.17	677,534.17	Utah		
Vermont.....	3,015,174.81	1,462,884.46	1,462,884.46	1,462,884.46	1,462,884.46	1,462,884.46	1,976,543.54	876,536.18	160.3	876,536.18	876,536.18	0.1	451,065.40	451,065.40	Vermont		
Virginia.....	13,039,168.70	7,071,740.41	6,071,740.41	6,071,740.41	6,071,740.41	6,071,740.41	6,219,050.97	2,035,342.28	281.6	735,786.56	735,786.56	23.2	4,192,442.84	4,192,442.84	Virginia		
Washington.....	13,352,504.18	6,117,211.87	556.7	2,429,355.02	1,046,687.39	94.6	6,219,050.97	2,948,743.65	626.6	1,997,405.00	613.1	631.1	731,401.44	731,401.44	Washington		
West Virginia.....	7,343,200.86	3,250,253.33	356.7	282,663.30	123,013.89	12.8	6,979,050.76	2,787,834.00	185.6	777,918.20	256,315.54	28.7	118,518.74	118,518.74	West Virginia		
Wisconsin.....	21,807,140.91	8,919,640.42	8,919,640.42	8,919,640.42	8,919,640.42	8,919,640.42	1,047,871.55	3,037,777.40	821.6	4,274,841.24	2,787.5	6.5	3,486,603.45	3,486,603.45	Wisconsin		
Wyoming.....	8,809,819.33	4,319,036.56	982.0	814,867.50	521,673.56	80.3	3,539,213.43	1,529,669.59	31.7</								